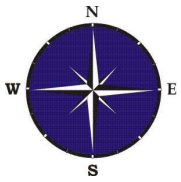


TRITON ROBOTICS

Memo

To: Dr. Marek Kujath

From: Aaron Caldwell, Michael Carter, Guillaume Gervais, Amy MacFarlane, Jeramy Slaunwhite, Rob Vaughan

CC:

Date: April 8th, 2005

Re: **Final Report for Robotic Vessel**

Dear Dr. Kujath,

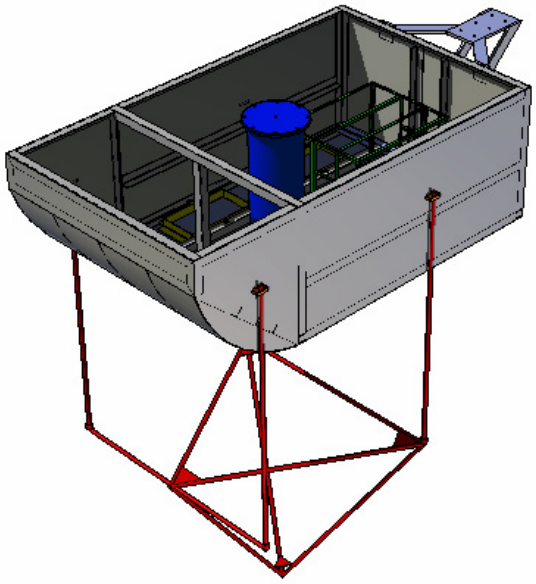
Please accept the attached document as our final report that details our progress to design and construct a robotic vessel as requested by our client the Project AQUA Research Group. The construction of this vessel took place between January and April of 2005. We trust that this document will satisfy the requirements for completion of the winter term for MECH 4020 – Design Project.

Best Regards,

Rob Vaughan
For Triton Robotics

FINAL REPORT

TRITON ROBOTICS



MECH4020 DESIGN PROJECT

FINAL REPORT

TRITON ROBOTICS

Team #9
Aaron Caldwell
Mike Carter
Amy MacFarlane
Guillaume Gervais
Rob Vaughan
Jeramy Slaunwhite

Supervisor: Dr. Marek Kujath
Client: Project Aqua

Date: April 8, 2005

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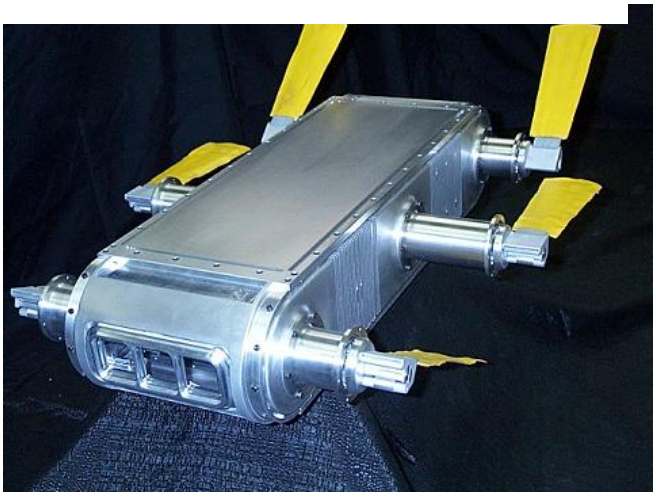
1.0 INTRODUCTION

Triton Robotics has been contracted by the Project AQUA research group to design and build a mobile robotic vessel for the purposes of tracking and position monitoring of an underwater walking/swimming robot (AQUA). The robotic vessel will carry a suite of sensors for the accurate positioning of the underwater robot and the vessel itself.

The members of Triton Robotics are six senior year mechanical engineering students at Dalhousie University in Halifax, Nova Scotia, under the direction of Dr. Marek Kujath. This project is scheduled for completion in April of 2005.

1.1 PROJECT AQUA

Figure 1 AQUA Underwater Robot



"AQUA is a joint project between McGill University, York University and Dalhousie University …". The goal of this project is to "explore the science technologies for the interpretation of underwater video footage, the identification of underwater features, the modeling of 3-D scenes using vision and acoustics, vehicle control, position estimation and mechanical design." This project is funded by the Institute for Robotics and Intelligent Systems (IRIS), a Canadian National Center of Excellence. Supplementary funding is also provided by the National Sciences and Engineering Research Council (NSERC). Refer to Figure 1 – AQUA Underwater Robot.

The AQUA Project as a whole is broken up into three parts:

- McGill University is responsible for developing the swimming robot and using pictures to allow the robot to determine its position, orientation and directional velocity.
- York University has been appointed the task of developing a 'trinocular' stereo camera used to take pictures used to build 3-D models of what it 'sees'.
- A team at Dalhousie University is currently developing a vessel to be used for tracking the position of the underwater robot using a series of sensors.

1.2 PROJECT OBJECTIVES

Triton Robotics will deliver to the client a working prototype that meets the requirements as stated in section *2.0 Design Requirements*. The final objectives of the project are:

- Delivering a working prototype capable of remote manual remote control by April, 2005.
- Delivering documentation that describes the design and construction of the robotic vessel.
- Delivering procedures for the purposes of standard operation and maintenance.

The completed robotic vessel will be delivered to the Project AQUA group. Upon delivery, the members of Project AQUA plan to use this vessel as a prototype. They will then perform tests to determine the effectiveness of the robotic tracking system. The AQUA group also plans to improve upon the robotic vessel, pending the availability of funding.

2.0 DESIGN REQUIREMENTS

The essential requirements for this project are outlined below:

- Dimensions of the vessel will not exceed 72" long, 48" wide, or 38" high to enable transport of the vessel in the rear of a minivan.
- The weight of the vessel, in air, not including batteries and hydrophones, will not exceed 200 lbs.
- The vessel will be capable of operating and maneuvering at a roll angle of 18 ° without degradation.
- At a minimum, the maneuvering system will control the vessel's motion in two horizontal DOF; surge and yaw. The vessel will have a zero turning radius.
- The maneuvering system will be battery powered.
- Batteries will be easily removable for replacement and/or recharging.
- The vessel will be capable of remote manual operation, adaptable for autonomous control.
- Provisions for the mounting of the electrical payload, including the following, will be provided:
    - Inertial Navigation Sensor
    - Digital Compass
    - Camera with USB interface
    - Laptop or PC Tower
    - Two Inclinometers
    - Differential GPS
    - Wireless Ethernet card
    - Data Acquisition Board
    - Inverter
- Means will be provided for mounting four Dolphinear hydrophones.
- Budget for handover of project deliverables will not exceed $ 7,200 CDN:
    - Propulsion system - $3,600 CDN
    - Frame for electrical equipment - $1,000 CDN
    - Waterproofing - $1,000 CDN
    - Vessel Construction - $600 CDN
    - Miscellaneous expenses - $1,000 CDN
- The vessel will be capable of at least two knots (~1 m/s) speed over bottom in "Moderate Breeze" conditions (i.e. Beaufort Force 4 or 11 to 16 knots wind speed), in a current of 2 knots.
- Operational endurance will be at least 2 hours at 75 % of maximum thrust.
- Vessel will be designed for operation in fresh or salt water and of corrosion resistant construction.

- Mounting arrangement for hydrophones should be very rigid and sturdy to maintain a precise distance between the hydrophones.
- Hydrophones should be submerged one meter below surface of water.
- Vessel will be capable of manual remote operation from shore to location of underwater robot then switched to autonomous control for tracking of underwater robot.
- Waterproofing of the electrical components of the raft is necessary. Provision will also be made for cooling electrical components.
- Unobstructed field of vision for the underwater camera is required.
- Construction materials and electrical equipment magnetic field considerations concerning possible influence on digital compass will be considered.

2.1 DELIVERABLES

Due by April, 2005 Triton Robotics will deliver the following to the client:

- A working prototype capable of remote manual control, documentation of the design and construction of the vessel and a procedures and maintenance manual. The contractor will provide training to Dr. Pifu Zhang and Weimen Shen for the purposes of operation and maintenance.
- The contractor will not be responsible for the installation of any electrical equipment except that necessary for the manual operation of the vessel.

2.2 INTELLECTUAL PROPERTY

The prototype vessel will be the property of PROJECT AQUA. The contractor has agreed to sign an Intellectual Property Agreement with the client for any future commercialization of the prototype vessel.

2.3 CLIENT RESPONSIBILITIES

- The client is responsible to cover the cost of building the prototype up to $ 7,200 CDN.

3.0 DESIGN SELECTION

The design of the vessel was approached by starting with the hull shape. The criteria matrix below shows the initial designs considered and the criteria used to rank them. This process resulted in the selection of four hull designs which were modeled in a tow tank at Dalhousie University. The results of the testing will be discussed within the sections to follow. A Work Breakdown Structure was also drafted in order to provide a general outline of all project components that would need to be considered. This can be seen in *Appendix C – Work Breakdown Structure.*

3.1 Design Selection Ranking

Table 1 - Design Selection Ranking

	CRITERIA
A.	Safety of operation.
B.	Relative volume of hull shape.
C.	Weight characteristics of hull shape.
D.	Stability of hull shape.
E.	Magnitude of turning radius.
F.	Speed capabilities.
G.	Capable of two degrees of freedom in the X-Y plane.
H.	Relatively low power requirements.
I.	Capable of mounting a hydrophone array to the hull.
J.	Provides an unobstructed field of view for a camera.
K.	Simplicity of design.
L.	Placement of battery packs.
M.	Sea-Keeping

All criteria were scored on a scale of 1-3 with 3 being the best.														
DESIGN	A	B	C	D	E	F	G	H	I	J	K	L	M	TOTAL
Catamaran	3	2	2	2	2	3	1	3	1	2	2	2	2	27
SWATH	3	2	2	3	2	2	1	3	3	2	2	2	3	30
Spider	2	2	1	2	3	1	3	2	1	2	1	1	1	22
Disp. Hull	3	3	3	1	1	2	2	3	1	3	3	3	2	30
Tube Hull	3	2	2	2	3	1	3	2	1	3	1	2	2	27

Due to its low score, it was determined that the spider shaped hull, which is a series of hulls connected by radial arms, was not feasible and the idea was disregarded. Upon further consultation with the client and faculty advisor Dr. Kujath, it was decided that the SWATH (Small Water Plane-Area Twin Hull) was far too complex and should also be disregarded. The displacement, large catamaran, short catamaran and tubular hull designs were selected for further investigation. These four designs are outlined in greater detail below.

TUBULAR HULL

The tubular hull (see Figure 2) design was chosen because of the inherently low turning radius associated with a circular shape. This design proved to be quite adept at turning but also developed poor directional stability when placed in the tow tank. Because of the hole through the center of the model, the two planes provided opposition to movement through the water.

Figure 2 - Tubular Hull

SMALL CATAMARAN

This model performed better than the tubular hull but failed to fully support the weight of the model hydrophone array. As the model moved forward, the nose would tend to dive, eventually bringing the top deck to the water and substantially increasing the drag. The large catamaran (see Figure 3) proved to be better at this.

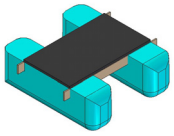


Figure 3 - Catamaran Hull

LARGE CATAMARAN

The larger version of the catamaran (see Figure 3) performed well in the trials, supporting the hydrophone array and moved well through the water. The extra floatation in the longer pontoons kept the nose up when moving forward. The longer pontoons did however show a longer response time when turning due to the greater area in contact with the water plane.

DISPLACEMENT HULL

Similar in design to a standard ship's hull, this model (see Figure 4) proved to move well through the water and outperformed the catamaran designs in turning ability. This design also lends itself to the arrangement of the electrical equipment.

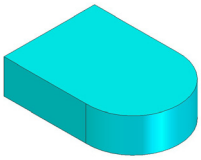


Figure 4 - Displacement Hull

PROPULSION DESIGNS

From initial research, it was determined that the selection would hinge on two types of propulsion arrangements. These two options included a fixed arrangement, similar to the thrusters found on ROVs, and azimuthal motors, termed "Z-Drive" motors.

Z-Drives are able to rotate 360^{o} about their vertical shaft while providing thrust in any direction. The use of these motors in conjunction with one another provides a high level of maneuverability coupled with the ability to provide significant thrust

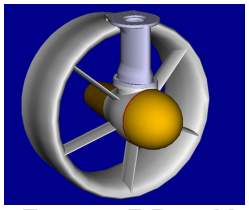


Figure 5 - Z-Drive Motor (www.ptc.com)

in one direction. This arrangement also provides an efficient use of power, limiting the vessel's response time when given an input by the user. Please refer to the image of a Z-Drive motor presented in Figure 5.

The arrangement of the four fixed thrusters is non-traditional and is not commonly used in industry. It offers a zero degree turning radius and a certain level of simplicity. However, it does not provide an equal level of thrust in forward and reverse and lacks maneuverability at high speeds.

The arrangement of the two transverse thrusters coupled with two fixed thrusters is a common commercial arrangement, providing good maneuverability and a zero degree turning radius. It does however require a more complex control system than the four fixed arrangement and also provides unequal thrust in forward and reverse. Both arrangements using fixed thrusters provide an inefficient response to input from the user, increasing the amount of time required to turn the vessel.

The use of a rudder was also considered. This practice is common on commercial vessels but does not lend itself to a tight turning radius. As a zero degree turning radius is required for this project, the use of a rudder was disregarded.

3.2 MODEL TESTING

The four main hull designs considered were constructed at a ¼ scale and tested in a tow tank in order to gather comparative data describing drag resistance, maneuverability and stability. A ¼ scale model of the hydrophone array was also constructed and attached to each hull model during testing. The results of the tests are output in the form of Effective Horse Power (EHP). This number gives the user an indication of how much horse power will be required to propel the full scale model. A brief overview of the test results are as follows, in Table 2:

Table 2 - Tow Tank Testing Results

Hull Shape	Towing Speed (m/s)	Full Scale Speed (knots)	Full Scale EHP	Comments
Displacement	0.51	1.94	0.21	Good stability, bow remained above surface
Large Catamaran	0.51	1.94	0.22	Good stability, bow remained above surface
Small Catamaran	0.51	1.92	0.33	Bow remained above surface, pitched forward slightly
Round	0.51	N/A	N/A	Bow nosedived: No data

This initial tow tank testing proved to be ineffective due to the nature of the mount used to tow the models through the tank. Located at the top and center of the models, this method of propulsion caused the nose of the models to dive into the water due to the heavy drag provided by the model hydrophone array. A more practical arrangement for the propulsion involves the application of force from

beneath the vessel at the rear. A device was fabricated by the team to pull the models by hand through the tank with the application of force below the water. This testing proved to be much more successful. All of the models managed to keep their bows above water. The results of this test showed that the long catamaran and the displacement hull supported the hydrophone array in an effective manner and provided the least resistance to motion through the water. Secondary tow tank testing was performed on the models without the hydrophone array using a spring scale and stop watch. Please refer to *Appendix E – Hull and Propulsion Calculations* for more information.

3.3 SELECTED DESIGN

Due to the complexity of the overall design it was decided that, for the initial design selection, all components be grouped into one of the following five major areas (see Figure 6) which will be discussed in detail below:

- Hull
- Hydrophone array
- Propulsion
- Electrical equipment
- Control System

HULL

It was determined that the conventional displacement hull design was best suited for the particular application of this project. The wide mono-hull design will provide a large payload capacity as well as good transverse and longitudinal stability. One of the client requirements dictates that a camera should be installed such that it can gather images below the surface of the water under the vessel. The flat bottom design of the hull will allow easy installation of a clear viewing port to accommodate this requirement. Large displacement hulls are optimally operated at low speeds, which corresponds to the speed set in the design requirements.

This fundamental hull shape will be straightforward to construct and can be easily designed to allow center of gravity adjustment, water contact cooling for electrical equipment and vertical adjustment of the propulsion/hydrophone array systems. The adjustability of the design is desirable because the client requires the vessel to be fully operational with and without the hydrophone array attached. In comparison to the catamaran, the displacement design will require less hull material, resulting in a lighter vessel.

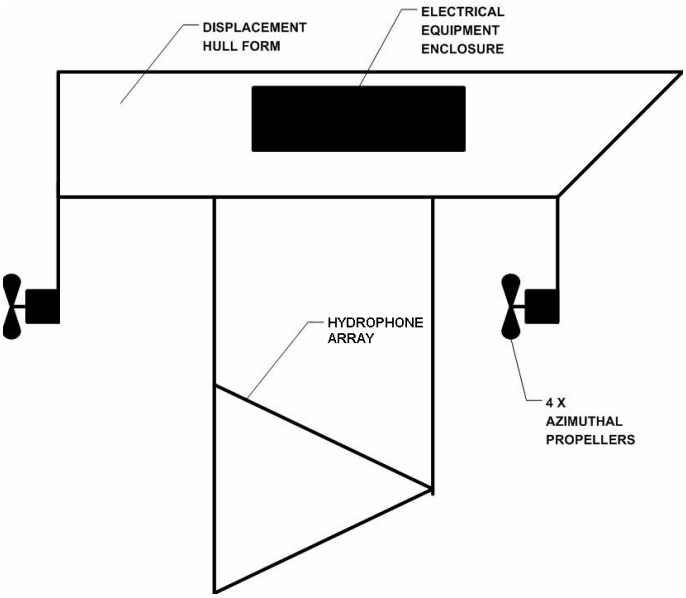


Figure 2 - Displacement Hull with Hydrophone Array

- Based on a total weight of 400lbs, the displacement hull will be approximately 60" long, have a beam of 42", and a total height of 24".
- The entire electrical payload will be accommodated in the displacement hull.
- The hydrophone array, which will be discussed in the next section, will be attached to the hull using a metal frame.

HYDROPHONE ARRAY

It was decided that the hydrophone array should be constructed of a very light material, such as carbon fiber or aluminum. It should be constructed in such a way that each of the four hydrophones be located 1m center to center from the others. A rigid frame ensures the location of the hydrophones remains constant relative to one another. In order to isolate the hydrophones from acoustic noise, the array should extend approximately 2 meters below the surface of the water. Consisting of four hydrophones, the array assumes a pyramid structure to maintain the required spacing between the sensors. Refer to Figure 6 for a view of the proposed array model.

PROPULSION

It was initially determined that an arrangement of 4 z-drive motors positioned on the corners of the vessel be used for the propulsion system. After further investigation however, it was decided that two z-drive motors should be sufficient. Z-drives are commonly used in dynamic positioning situations such as the one presented within the scope of this project. The motor arrangement should provide maximum control and a zero degree turning radius. In contrast to all other propulsion arrangements, the 2 z-drives can be turned to thrust in any given direction. This translates into high maneuverability, and efficient use of battery power. The only drawback to these types of drives is the increase in system complexity.

ELECTRICAL EQUIPMENT

It was decided that all electrical equipment should be stored on board in waterproof electrical enclosures. All enclosures, batteries and wiring should be mounted to a frame that can be easily removed from the vessel. This will aid in the ease of overall maintenance and transportation. 12 volt batteries should be used to power all electrical systems. As the onboard computer system and hydrophone array data acquisition board require AC power, an inverter and transformer will also be required. The batteries will be the greatest portion of the payload weight. They will be placed on the vessel in such a way that the load is evenly distributed and will aid in increasing overall vessel stability. The camera used for locating the ROV when the hydrophone array is not in use will be mounted to the bottom of the vessel on a glass plate or window in order to provide an unobstructed underwater view. A metal frame will be constructed to house the Crossbow Inertial Sensor at the center of gravity (CG) of the vessel. This frame will allow the navigational system to be calibrated so the distance from the center of the Crossbow to the focal point of the camera is known.

Heat dissipation may be required for the compartments containing the computer tower, inverter and transformer. This will most likely be accomplished using a fan coil, extra fans or a cooling block directly on the sources of heat. After a thermodynamic analysis is performed to determine the amount of condensation to be expected, a sufficient amount of absorbent material will be installed to ensure no water comes into contact with the electrical equipment.

CONTROL SYSTEM

The control system will consist of a remote control unit that will transmit radio signals to six servo mechanical motors, via a receiver. This arrangement will provide a mechanical solution to controlling and operating the vessel. The servos will be used to independently control the speed and direction of both the bow and stern motors. One servo will be dedicated to perform a kill switch operation. This one of the safety features that this robotic vessel will be equipped with.

4.0 CONSTRUCTION DETAIL

The overall design may be broken down into five main elements (see Drawing RV-000-00 General Arrangement):

- Hull
- Hydrophone array
- Propulsion
- Electrical equipment
- Control system

Although each element will ultimately be integrated into our completed design; for the purposes of a description of construction details each will be examined separately.

4.1 HULL

Triton Robotics chose aluminum as the material for hull construction. Aluminum was chosen for its strength, light weight, and corrosion resistance. In addition, aluminum is a forgiving material for vessel construction, readily able to be cut and re welded to allow for modifications or design changes.

The hull is a simple, flat bottomed, barge type design; overall length: 60", breadth: 42", depth: 24". The construction of the hull consisted of aluminum sheet welded over an arrangement of longitudinal and transverse frames. (See Figure 8)

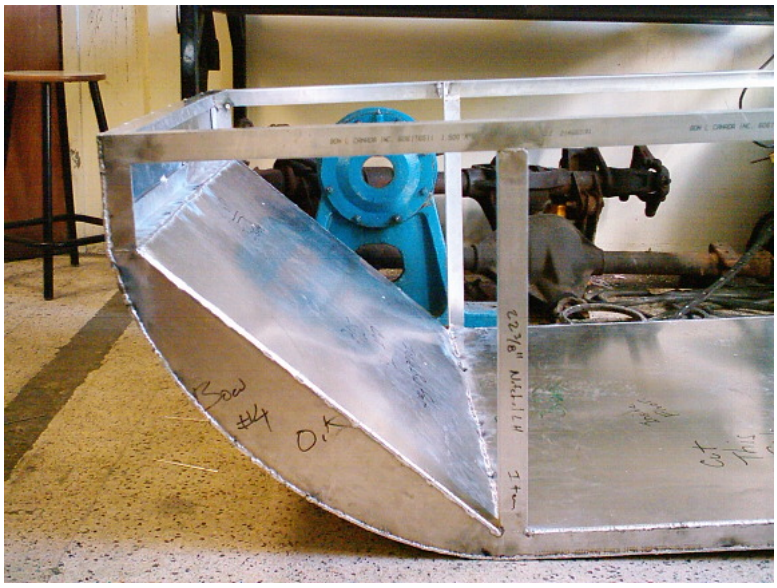


Figure 8 – Hull Frame Arrangement

The outer hull plating is 5052-H32, 0.081" thick aluminum sheet. The hull is flat bottomed over 40" of its length, as measured from the stern. The bow portion of the hull comprises the forward 20" of the hull length. The bow shape is a simple 25" radius rising from the flat bottom to a flat prow, which extends 6" down from the gunnels. (See Drawing RV-100-02 Hull Frame Dimensions) The hull is flat sided with a square stern. A flat deck covers the forward 20" and the aft 12"of the hull. For watertight integrity, all outer hull joints were must be fully welded.

The bottom framing arrangement is of 1 ½" x 5/32" 6061-T61 aluminum channel and 1 ½" x 1 ½" x 1/8" 6061-T61 aluminum angle. The channel was used on the two longitudinal bottom/side seams, the transverse bottom/stern seam, and transversely where the bow radius begins. Two longitudinal angle frames are used for stiffening over the flat bottom section.

Stern transom framing is comprised of (in addition to the 1 ½" x 5/32" 6061-T61 aluminum channel at the stern/bottom seam) five sections of 1 ½" x 1 ½" x 1/8" 6061-T61 aluminum angle; two vertical corner pieces at the stern/side seams, a gunnel piece, and two vertical stiffeners.

Transverse framing was incorporated where the bow radius begins its rise from the flat bottom and 12" forward of the stern transom. This is similar to the stern transom framing, being comprised of (in addition to the bottom channel) 1 ½" x 1 ½" x 1/8" 6061-T61 aluminum angle.

The bow framing consists of five sections of 5052-H32, 0.081" thick aluminum sheet cut to the bow radius curvature of 25". These pieces were bent to add structural stability to the bow of the hull. The flat 6" deep bow section was framed with four sections of 1 ½" x 1 ½" x 1/8" 6061-T61 aluminum angle pieces.

A watertight floor arrangement was constructed by having pieces of aluminum sheet cut to fit on top of the floor longitudinal members. (See Drawing RV-100-05 Hull Floor Arrangement). All welds holding the water tight floor were inspected for leaks and repaired as needed. Inserted inside the water tight floor cavity will be expandable, high density foam.

The cargo cover consists of a 1 ½" x 1 ½" x 1/8" 6061-T61 aluminum angle framing arrangement that is covered by a piece of 5052-H32, 0.081 thick aluminum sheet. (See Drawing RV-100-07 Hull Cover Arrangement).

After the welding of the bottom, side, stern, and inner floor panels to the framing arrangement it was necessary to cut an opening for the installation of the camera enclosure (See Drawing RV-301-01 Camera Arrangement). It was a requirement of our client that the gyroscope be located at the center of gravity of the vessel and be in close proximity to the camera located inside the camera enclosure. It was also desired that the vessel float at an even trim with the center of gravity at this location. To do this we had to chose a gross operating weight, and at the corresponding even keel draft locate the center of buoyancy.

Figure 9 Hole Insertion

A gross operating weight of 575 lbs was selected, corresponding to a draft of 7 ¾". Using a Maple computer program (written by Triton Robotics, see **Appendix** D) the center of buoyancy was located to be 24 5/8" forward of the stern. A 10" diameter hole was cut though the inner and outer hulls for the installation of the camera enclosure (See Figure 9).

To properly position the two trolling motors that are the propulsion system used for the vessel, 12 aluminum ½" diameter bolts were permanently welded to the hull. The 12 aluminum bolts were welded to a sub frame assembly that is enclosed by the bow and stern permanent covers. (See Figure 10).

Please refer to Appendix D for detailed Hull and Propulsion Calculations for this vessel.

Figure 10 Motor Mounting Bolts

4.2 HYDROPHONE ARRAY

The array is a frame design consisting of 1" x 1" x 1/8" aluminum angle. Aluminum was chosen because it is inexpensive relative to other rigid marine application materials and to remain consistent with the rest of the vessels construction. Using aluminum for the construction of the hydrophone array acts as a safeguard against galvanic circuit formation between the hull and the array. The hydrophone array protrudes ~1.89m below the waterline.

Four Dolphinear hydrophones will be mounted onto plates welded on a tetrahedral truss, outlining the shape of the hydrophone array. The hydrophones have not yet been mounted onto the hydrophone array as it is under our clients' scope of work. This truss will consist of six - 44" long members. This truss is then suspended from the hull using four - 50" long pieces of angle. These pieces are clamped to the side of the hull utilizing four quick release clamps. The array frame can be disassembled for ease of transport. (See Drawing RV-200-01 Array – General Arrangement)

The tetrahedron shape of the hydrophone array consists of six - 44" long, 1" x 1" x 1/8" aluminum angle. The arrangement of the individual members that assemble to create the hydrophone array can be seen in drawing RV-200-02 Array – Exploded View. The front centre cross member of the tetrahedron is permanently mounted to the top triangular section of the hydrophone array.

The hydrophone array mounts to four pieces of aluminum angle that are welded to the port and starboard sides of the hull. These angles are notched for easy mounting of the four uprights of the hydrophone array via the quick release clamps.

4.3 PROPULSION SYSTEM

Triton Robotics uses two, 50 lb thrust, 12 volt electric trolling motors, model PD 50 for propulsion of the robotic vessel. (See Figure 11)

These trolling motors come equipped with foot pedal controlled 360^{O} electric steering. They have variable speed control in the forward direction, and produce a maximum thrust of 50 lb, while drawing 42 amps.

The factory supplied variable speed control and steering control systems were modified so as to be able to be controlled via a FM remote control system. A description of the control system may be found in Section 4.5.

The trolling motors are mounted on the hull centerline; one over the stern transom and one over the bow. Two mounting brackets of ¼" 5052-H32 aluminum plate were fabricated and welded to the factory motor brackets (See Figure 12). This enables the motors to be mounted/dismounted from the vessel without any disassembly of the motor assembly, as is necessary with the factory motor brackets.

Figure 11 MinnKota Trolling Motor

Figure 12 Motor Mounts

4.3 ELECTRICAL EQUIPMENT

Triton Robotics chose aluminum as the material for all electrical frame construction. The aluminum allows for lightweight, strong support for the containment of all the electrical components.

There is one main electrical frame to hold the computer tower, hydrophone array data acquisition board and power inverter. This frame (See Drawing RV-300-01 Electrical Enclosure) is of welded aluminum construction, overall dimensions 12 1/2" x 19 3/4" x 21", made with ½" x ½" aluminum angle which was fabricated from 0.081" thick 5052-H32 aluminum sheet. The electrical components are attached to two flat aluminum plates located within the frame.

The frame is secured inside a 22" x 20 1/2" x 5" aluminum enclosure (See Figure 14) designed to protect the electrical components. The enclosure is of welded 0.081" thick 5052-H32 aluminum sheet construction.

Camera enclosure (See Drawing RV-301-01 Camera Arrangement) was fabricated from 0.081" thick 5052-H32 aluminum sheet. The enclosure carries a Plexiglas viewing port to provide an underwater view for the camera. The enclosure is 100 % watertight to prevent flooding of the vessel should the Plexiglas or associated components fail.

Figure 13 Electrical Enclosure

An aluminum frame (See Figure 14) to mount the camera and gyroscope in the camera enclosure was constructed from 1/2" 6061-T6 aluminum square bar and 1/8" thick 5052-H32 aluminum sheet.

The four batteries will also be mounted to the vessel using small aluminum frames made of from 0.081" thick 5052-H32 aluminum sheet.

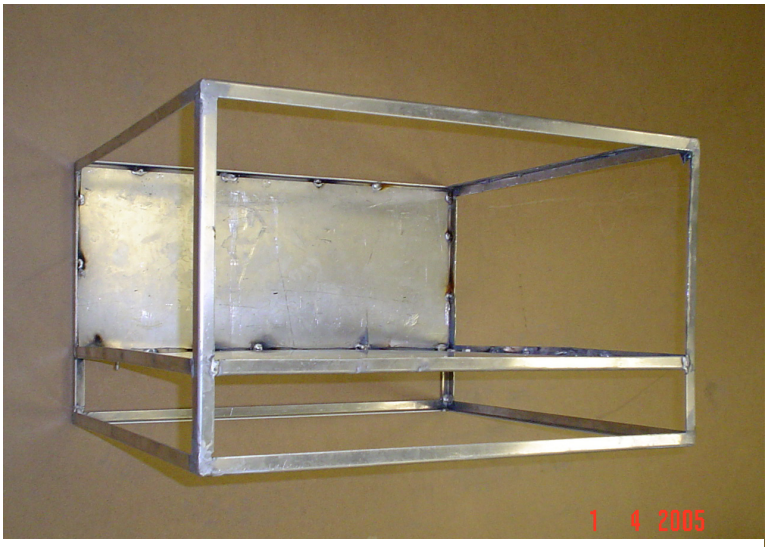


Figure 14 Electrical Frame

It was determined that two separate circuits would be incorporated into the electrical system; one for the motors and one for the electrical equipment.

The motor circuit consists of three 12V, 103 amp hr batteries, a negative and positive bus bar to distribute the power, two 50lb thrust trolling motors, a 50 amp breaker for each motor, a main kill switch operated by remote control and a grounding line. The grounding line is 6 gage wire and all other wiring is 8 gage. All connections are made through spade clips. Three small frames of aluminum construction were welded to the back wall of the hull to house the breaker system and bus bars. The breakers and

bus bars can however be removed from their frames by unscrewing a few small aluminum bolts.

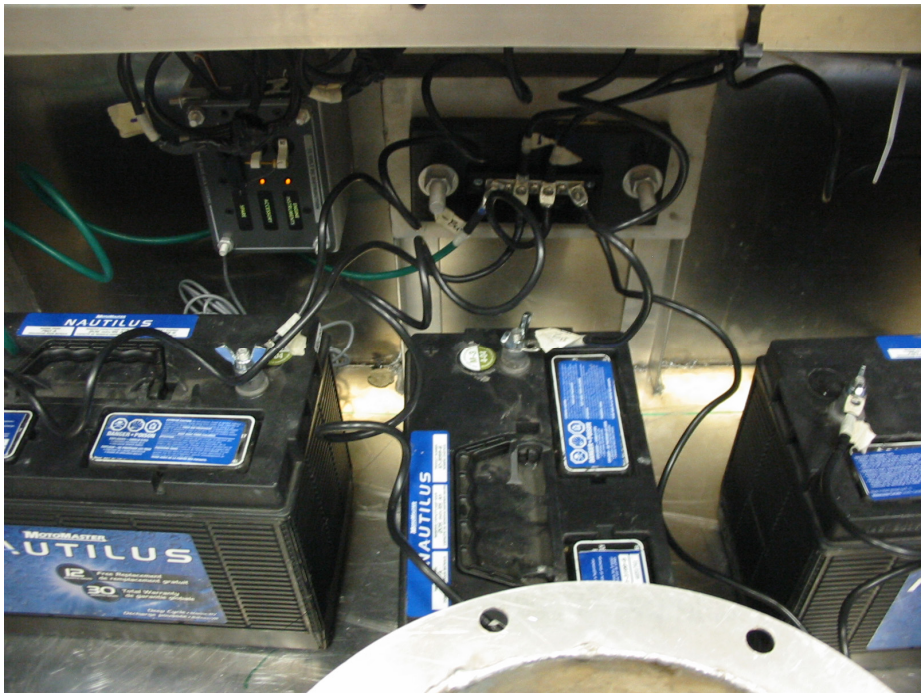


Figure 15 - Motor Circuit

Figure 16 60 Amp Fuse for Electrical Equipment Circuit

The electrical equipment circuit consists of one 12V 103 amp/hr deep cycle marine battery, a desktop computer, the Layla hydrophone stereo equipment, power inverter a grounding line and a 60 amp fuse to protect the equipment. The grounding line is standard 6 gage wire and all other connecting wires are standard 8 gage.

Several holes were drilled in top of the hull and the cover of the port hole to accommodate watertight fittings for the passage of motor, hydrophone and control leads. These permanent connections through the hull allow components to be easily plugged in from the inside and outside of the hull without running wires through the cover each time. This aids in keeping the hull water tight.

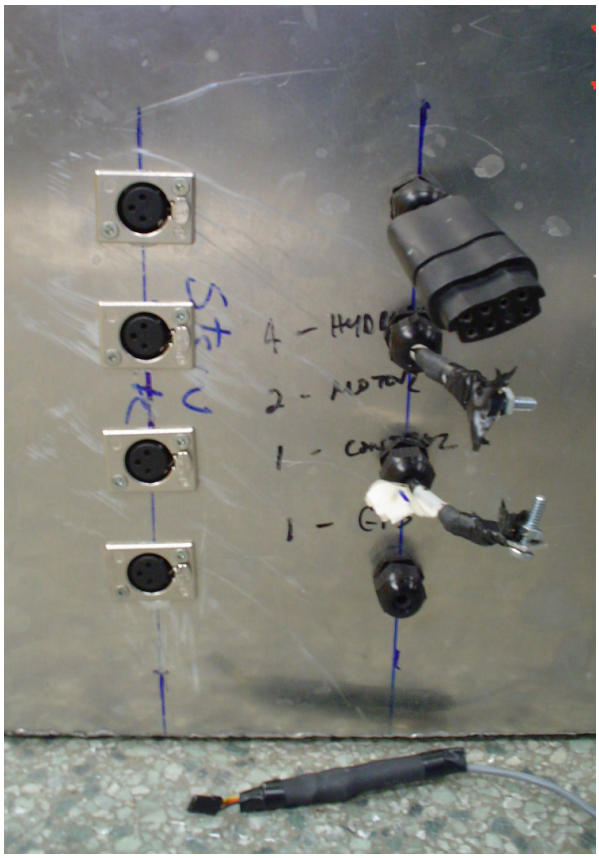


Figure 17 - Water Tight Connection – Hull Exterior

Figure 18 - Water Tight Connection - Hull Interior

4.5 CONTROL SYSTEM

The control system consists of the standard MinnKota trolling motors foot pedal controls integrated with a six channel FM radio control system. The stock foot pedals are designed to rest on the deck of a sport fishing boat so that an angler can control the boat with foot manipulations of the control pedal. Each foot pedal possesses throttle control, left and right steering, a constant – momentary control switch and a momentary button as shown below in Figure 20.

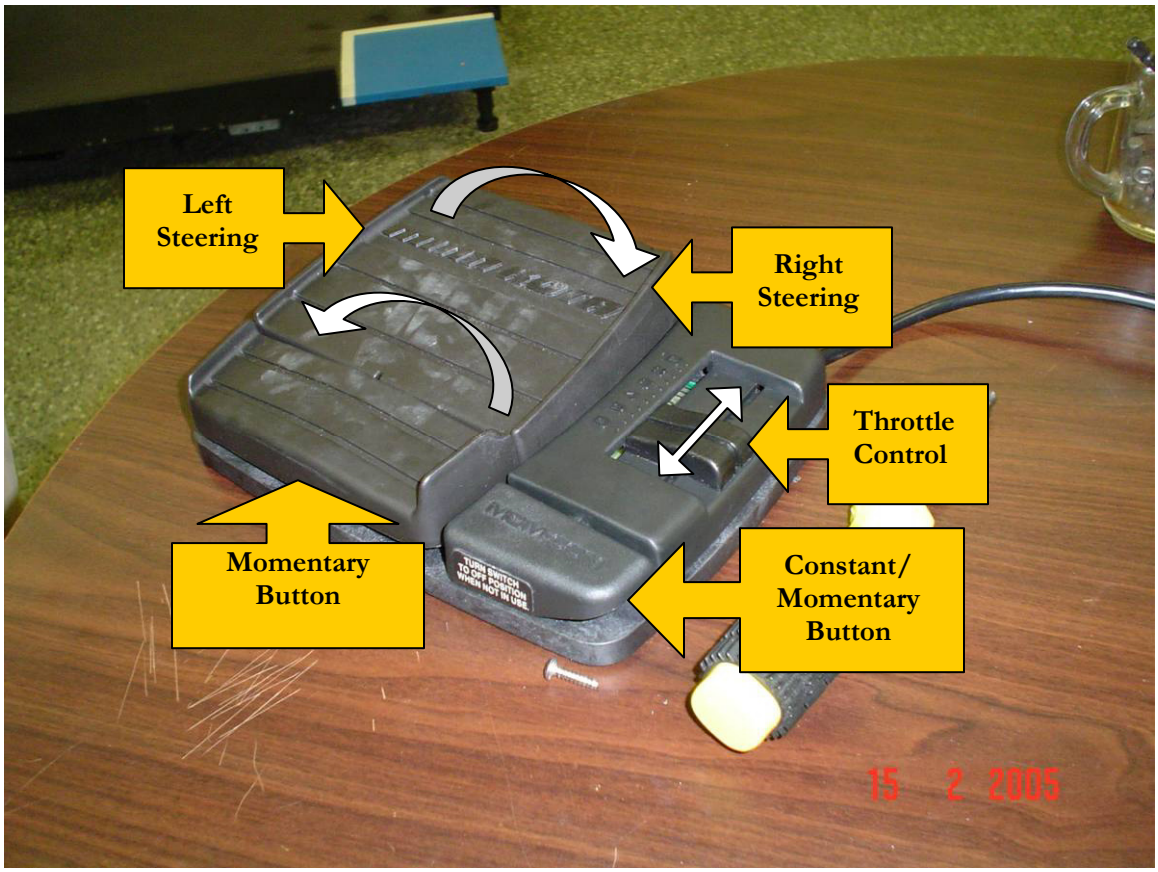


Figure 20 - Foot Pedal Controller

Actuation of these controls sends a signal from the internal circuitry, to the primary motor controller circuit. The primary functions necessary for remote vessel control are throttle control and steering.

Modifications:

Integrating the controls with the RC servo system was considered across two domains: electrical and mechanical. It was decided to take a mechanical approach due to the unknown electrical parameters within the primary motor controller circuitry. To maintain constant control opposed to momentary, the internal momentary selector button on the foot pedals were held in the depressed position using screws.

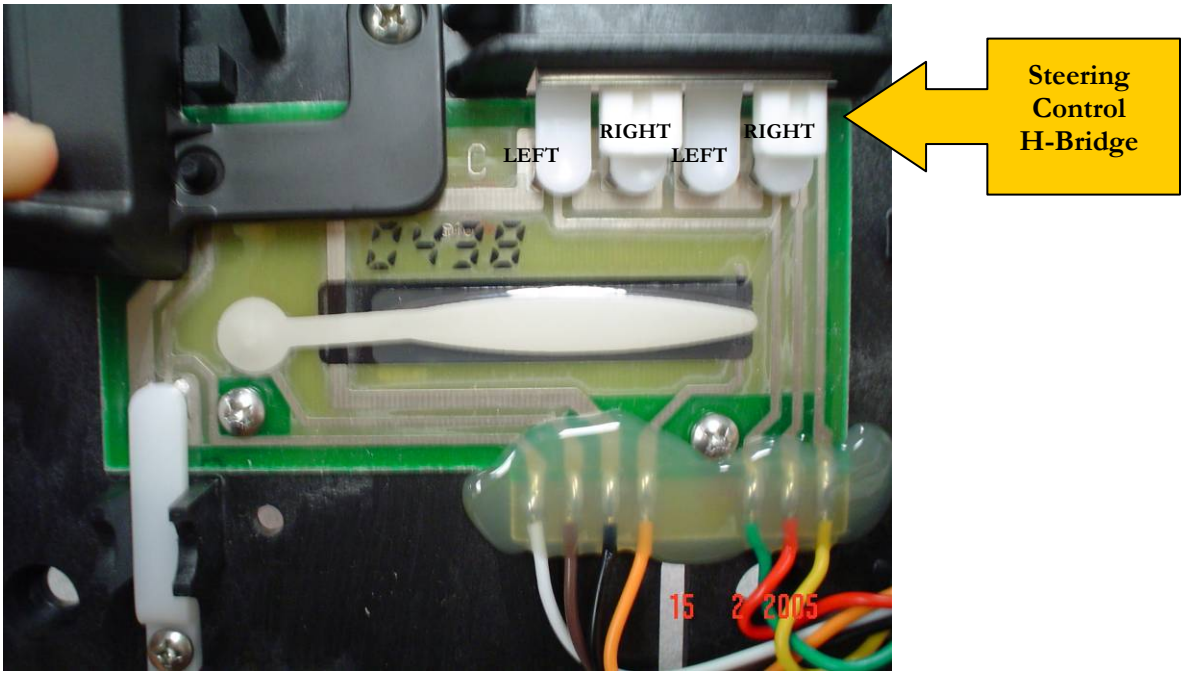


Figure 21 - Foot Pedal Circuitry

Throttle intensity is adjusted by sliding the button along its track. This was achieved remotely by connecting the slider to a simple linkage driven by a servo motor as shown in Figure 22. This allows a full range of throttle control from the remote transmitter controller.

Directional steering control is actuated by pressing on the left or right side of the steering pedal. This in turn causes a plastic mechanism to slide either to the left or right. The slider causes tabs to depress 2 button switches of an H-Bridge for each direction, (see Figure 21). Each pair of buttons cause the steering motor to energize clockwise or counterclockwise which turns the propulsion motor until the buttons are released. The motor remains at its orientation until the steering is actuated again.

Remote actuation of the steering control is achieved through the installation of a

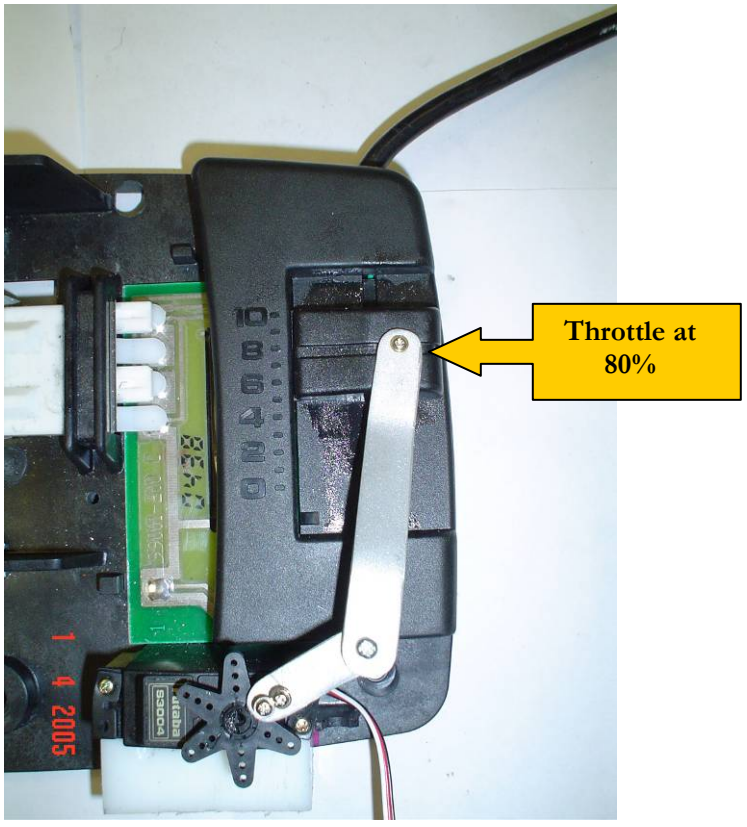


Figure 22 - Servo Actuated Throttle Control

manipulating rocker arm mounted on a shaft to simulate the rocker steering pedal as shown in Figure 23. The rocker arm is driven through a linkage by a servo motor to the left and right steering positions as demonstrated in Figure 23.

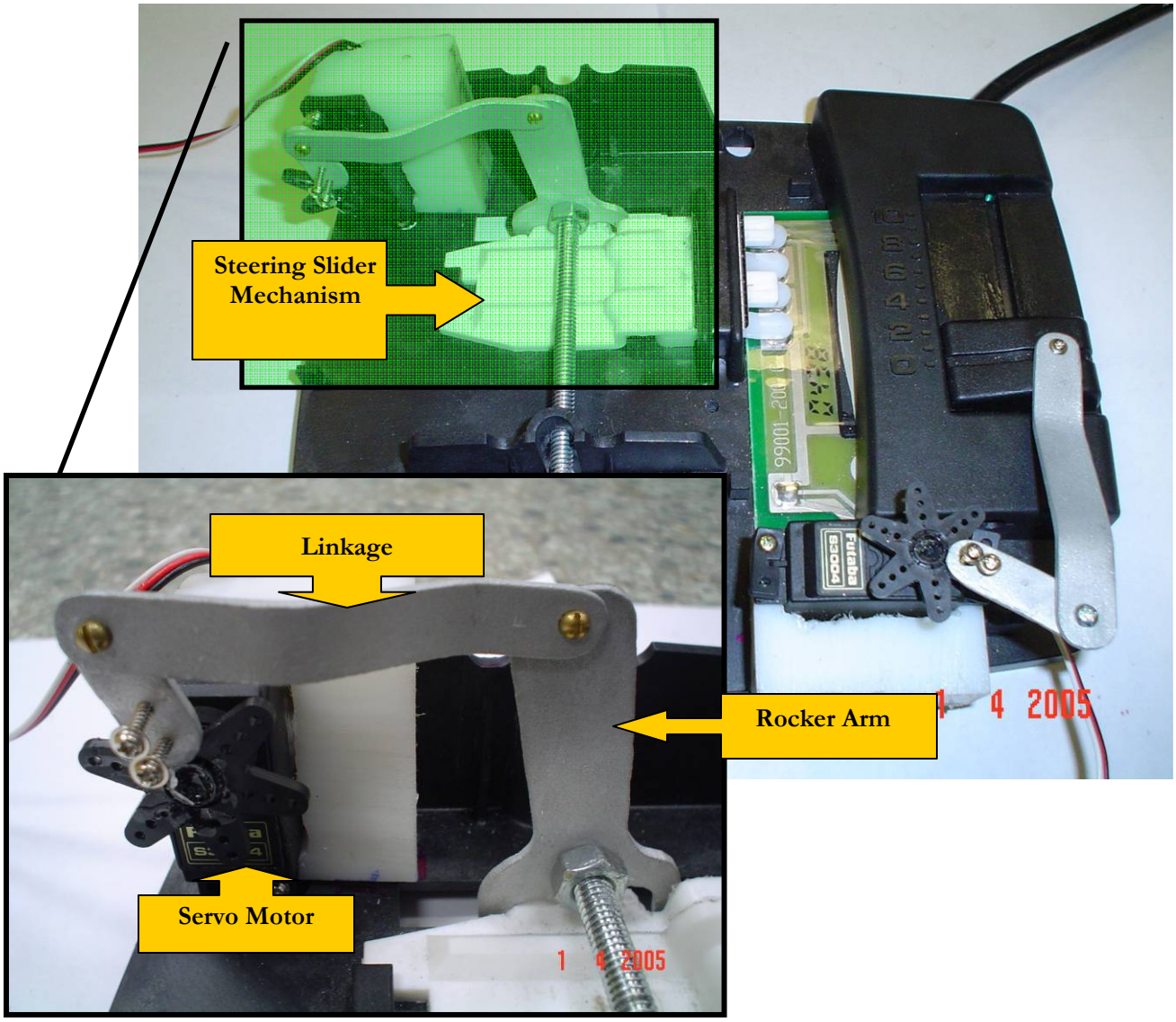
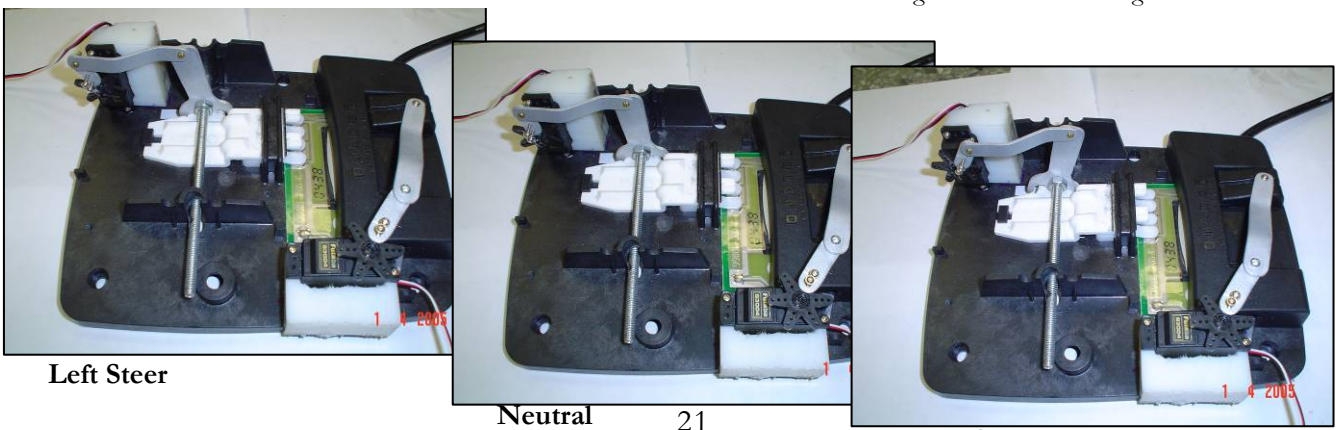


Figure 23 - Servo actuated Steering Control

Figure 24 - Servo Steering Positions



Left Steer **Neutral** **Right Steer**

The servo motors are fastened to molded polyethylene blocks which are attached to the deck of each control pedal.

Figure 25 - Breaker Panel

In addition to propulsion system control, a remote actuated kill switch was installed. The accompanied electrical system contains among other features, two 50 amp mechanical breaker switches. These breakers which allow current to flow to the motors can be switched remotely for safety purposes.

A servo motor is mounted to the breaker panel and a plastic arm switches the connected breaker switches Figure shows the servo arm in the off position. To reenergize the motors, the arm rotates clockwise which pulls a cord connected to the switches moving them to the on position.

5.0 TESTING

It is important to perform testing in order to define realistic requirements and measure actual results to see if previously defined requirements were met. The table at the end of this section contrasts the design requirements with all final results.

5.1 OUTBOARD TESTING

Location**:** Portuguese Cove Lake

Date: October 9th, 2004

Requirements:
The purpose of the test was to determine the thrust potential and endurance of an electric motor (figure 26) and a small freshwater fishing boat. There were no expected results for this test.

Figure 26 Electric Motor

Apparatus:

- 1 – Electric trolling motor (30 lbs of thrust)
- 1 – Automotive lead acid battery
- 1 – 15 foot flat bottomed freshwater fishing boat
- 3 – People aboard

Method:
Three team members boarded a 15 ft long flat bottomed boat. The boat was propelled by an outboard motor producing 30 pounds of thrust. The motor was powered using a small fully charged automotive battery.

Results and Discussion:
A speed of 2.38 knots was attained at maximum battery power. It was found that the battery (lead-acid automotive) had 45 minutes of useable power. The motor provided sufficient thrust for three people on board. Forty five minutes of useable power seemed be very encouraging since the battery used was small. Based on this test and some simple calculations, it was determined that using four deep cycle marine batteries would be sufficient.

5.2 INITIAL MODEL TESTING

Location: Sexton Campus
Tow Tank
Hydraulics Laboratory
Room D14

Date: October 29th, 2005

Requirements:
The purpose of this test was to obtain results that could be used to compare each of the potential hull designs. The test was also meant to help determine the full scale thrust required in order of reach the desired full scale speed of 4 knots.

Apparatus:

- 1 – Tow tank
- 1 – Towing sled equipped with sensors
- 4 – ¼ scale hull models
- 1 – ¼ scale hydrophone array model

Figure 27 Tow Tank Sled

Methods:
Four - ¼ scale models of the hull shapes being considered were built. These models were constructed using blue insulation foam and wood. A ¼ scale model of the hydrophone array was also built using steel. The models were dragged through the water by the tow tank testing apparatus (sled) shown in figure 27. The trials were automated and designed to record the velocity and drag force. The hydrophone array was attached to each model being tested. This created a significant amount of drag far below the waterline causing the models to "nose dive" into the water.

Results and Discussion:
Normally, the automated tow tank test yields values for the force, velocity, etc… However, due to the tendency for the models to "nose dive", the models were not able to move fast enough for data collection. These tests did allow for comparative analysis based on qualitative results. This made it possible to choose the appropriate model in a relative manner.

Figure 28a Displacement Hull Model

Figure 28b Long Catamaran Model

Figure 28c Short Catamaran Model

Figure 28d Tubular Hull Model

It was found that of the four models (Figures 28a, b, c and d); the displacement hull (far left) was best suited to meet the design requirements.

5.3 FINAL MODEL TESTING

Location: Sexton Campus
Hydraulics Laboratory
Room D14

Date: November 10th and 11th, 2004

Requirements:
At this point in the design process, it was necessary to know how much thrust was required to propel the full scale vessel maximum required speed of 4 knots.

Figure 29 Displacement Hull Model Testing

Apparatus:

- 1 – Towing stick
- 1 – Fishing line
- 1 – Spring scale (readings in pounds)
- 1 – Digital stopwatch

Methods:
This test consisted of dragging the displacement hull model with hydrophone array (figure 29) at a lower thrust point than during the initial model testing trials. Using the stick and fishing line, the model was dragged over a 5 meter distance. Using the digital stopwatch and spring scale, the elapsed time and force were then measured over this distance.

Results and Discussion:
The average velocity from these trials was ~3.25 ft/s. The measured force averaged at ~2.4 lbs. These values were then scaled up 4 times (full scale), the results of which are presented in figures 30 and 31.

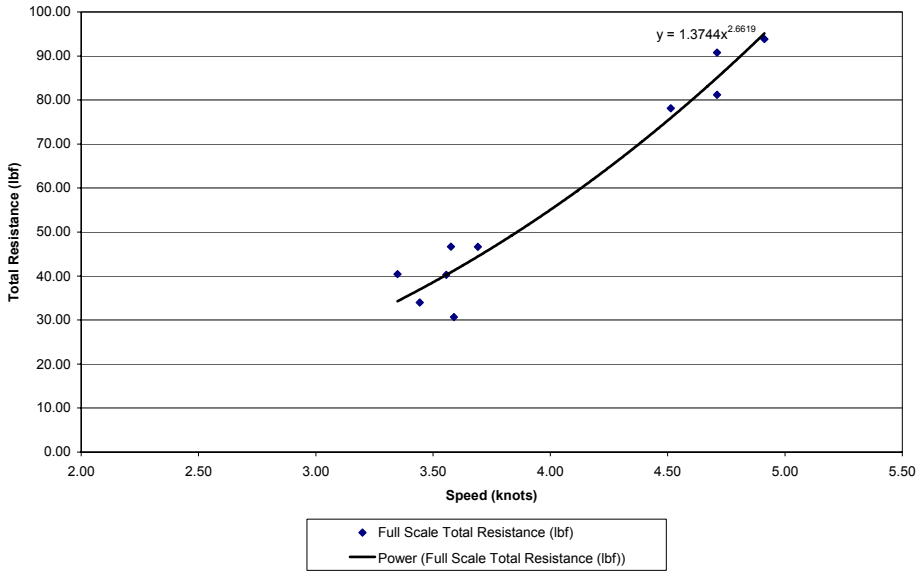


Figure 30 Resistance vs. Speed of Full Scale Displacement Hull (L = 5 ft, B = 3.5 ft)

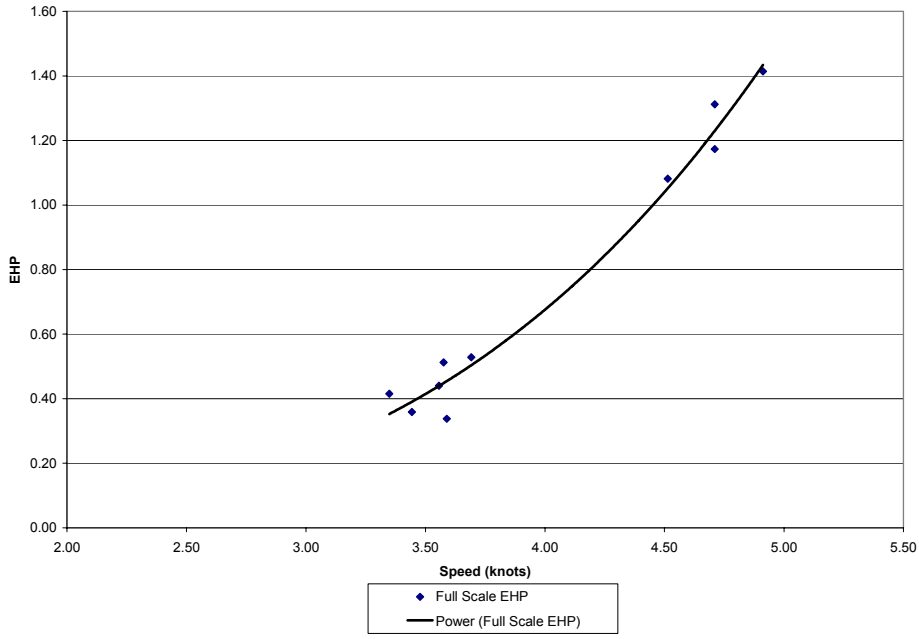


Figure 31 Effective Horsepower (EHP) vs. Effective Speed for Full Scale Model Displacement Hull (L = 5 ft, B = 3.5ft)

Based on figure 30 it was decided that the motors required a cumulative maximum thrust exceeding 55 lbf.

5.4 Initial Hull Leak Test

Location: Sexton Campus
Hydraulics Laboratory
Room D14

Date: February 4th, 2005

Requirements:
The purpose of this test was to determine whether the exterior hull would leak.

Apparatus:

- The hull
- Water hose (used to fill the boat)
- Spare hose and buckets (used to empty the boat)
- Red chalk (used to mark the seams)

Methods:
The hull was filled halfway (well above the anticipated draft line) with water using hose. Red chalk was then rubbed along the seams to help detect any possible leaks (figure 32).

Figure 32 Hull Leak Inspection

Results and Discussion:
The test was successful. There were no leaks detected. It was then determined that the hull was ready for testing in the Dalplex pool.

5.5 FIRST TRIP TO POOL

Location: Dalplex Pool
6260 South Street

Date: FEBRUARY 9TH, 2005
Requirements:
The purpose of this test was to qualitatively determine:

- The hull stability in the water (how does it react in water, how does it trim, etc…)
- Verify the watertight integrity of the exterior hull
- How stable the hull was on water
- To see how the hull trimmed (fore or aft heavy) and to further verify the hull's resistance to leaking.

Methods:
The hull was transported to the Dalplex and placed into the pool (figures 33a and 33b). It was then rocked in a variety of manners to determine the stability. Weight was also added in different areas to see how it would react.

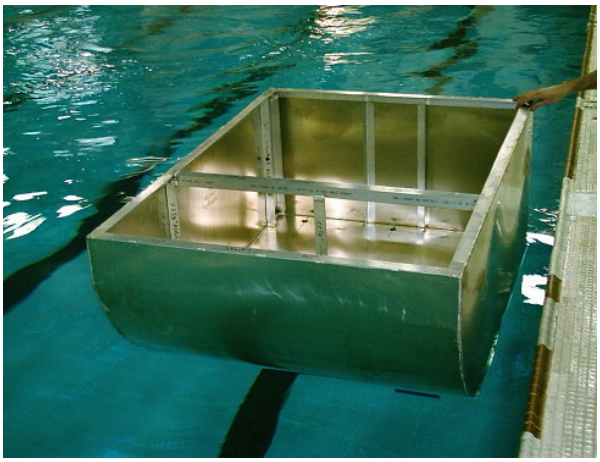


Figure 33a Hull Pool Test I

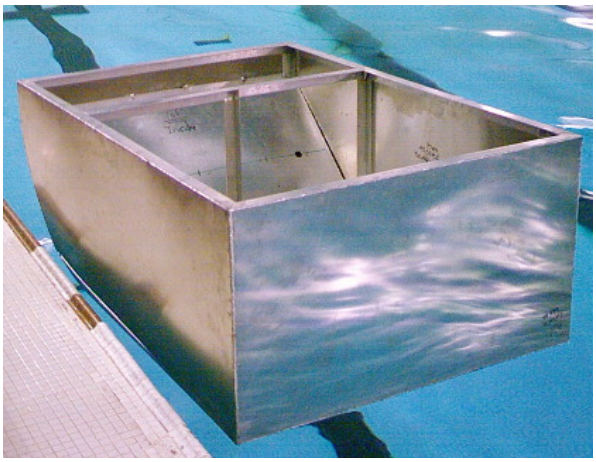


Figure 33b Hull Pool Test II

Results and Discussion:
It was found that the hull exterior was waterproof. It was also very buoyant. The hull could hold one person quite easily without increasing the draft significantly. The trim however was unbalanced in that the bow draft was greater that that aft draft. This would come into consideration in future efforts to balance the vessel.

5.6 LEAK TESTING THE PIPE

Location: Sexton Campus
IC Engines Laboratory

Date: February 2005

Requirements:
Upon installation of the electrical enclosure for the stereo camera and inertial sensor (pipe – figure 34), it was important to determine how well it was sealed. The

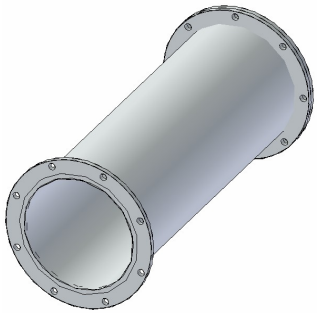


Figure 34 Camera and Inertial Sensor Enclosure

porthole needed to be watertight to ensure the sensitive equipment would be safeguarded and to minimize the risk of the hull taking on water.

Apparatus:
Water
Bucket

Methods:
The enclosure was filled with water. This simulated porthole failure for the inner hull while also testing the seal of the porthole itself. Any leakage was being monitored around the weld seams of the pipe and outer flange as well as the gasket outer gasket area.

Results and Discussion:
A drip leak was detected along the pipe. It was determined that this would only be an issue if the pipe remained filled on the order of days. Therefore it is of little concern since a detected porthole leak will not go untreated for more than on hour.

5.7 FIRST MOTORIZED TRIAL

Location: Dalplex Pool
6260 South Street

Date: March 16th, 2005

Requirements:
This test was performed to satisfy final inspection (see figure 35). The design aspects being tested were:

- Speed with the hydrophone array on
- Speed with the hydrophone array off
- Stability
- Maneuverability

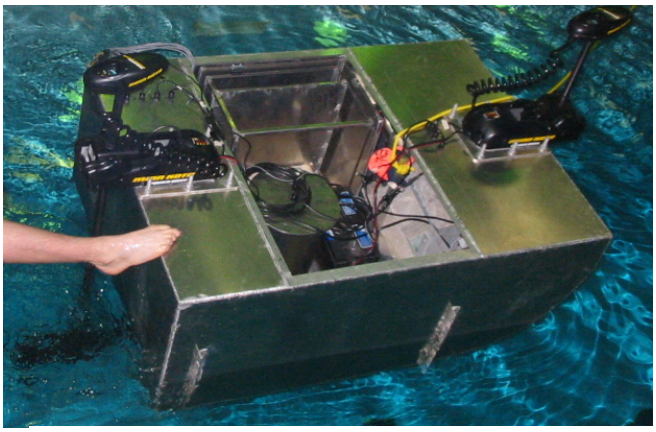


Figure 35 First Test of Full Assembly

The requirements of the design regarding these are as follows:

- The vessel was required to reach a speed of 2 knots in a moderate breeze (11-16 knots wind speed) in a current of 2 knots without the hydrophone array attached.
- There were no speed requirements *with* the hydrophone array attached.
- The vessel was required to operate at a roll angle of 18 degrees. This was not measured during testing; however the client is satisfied with this.
- The vessel was required to be controlled in at least 2 DOF (surge and yaw) and to also have a zero degree turning radius.

Apparatus:
- Full prototype without cover
- Tools
- ~135 lbs of concrete for ballast
- 1 – Truck (for transport)
- 1 – Dolly (for transport)

Methods:
The robotic vessel was placed in the water with the batteries, motors, circuitry, controllers and ballast on board. The vessel was then driven remotely. The tests performed included:

The speed testing with and without the array were the only quantitative tests performed during this first motorized pool trial. The vessel was accelerated at full thrust from a full stop, the elapsed time was measured from one checkpoint to another (start to finish) using a time clock hung on the wall.

Results and Discussion:
Figure 36 presents the results from the speed trials. The operator had some difficulty keeping the boat on a straight course during these trials. This may be in part due to inexperience controlling the vessel. The top speed of the vessel is expected to increase as the operator becomes more experienced. The speed requirement had not been met.

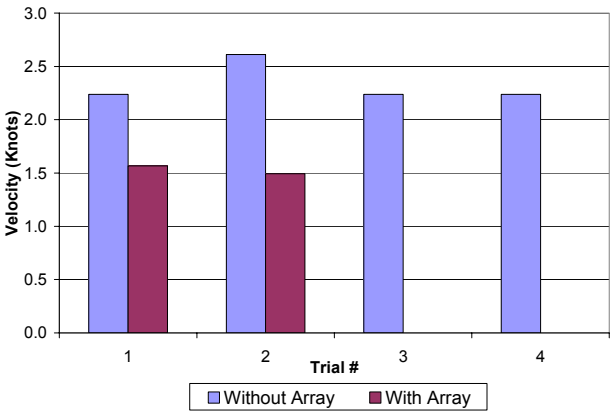


Figure 36 Measured Velocities in 1st Round Testing

The vessel appeared to be much more stable than when it was tested without the added weight of the batteries, motors, etc… The turning ability excellent; the vessel had a zero turning radius. Control of the vessel was effectively a 3 DOF operation.

Table 3 - First Trial Results Comparison to Design Requirements

Design Aspect	Design Requirement	Testing Result	Satisfied?
Speed without Array	Effectively 4 knots	2.61 knots	N
Speed with Array	N/A	1.57 knots	N/A
Stability	Operate at 18° roll angle	Qualitative results	No data - Client satisfied
Maneuverability/ turning	Zero turning radius	Zero turning radius	Y
Maneuverability/ control	2 DOF	3 DOF	Y

It was later found that the batteries used were mostly discharged before testing began. For this reason, the group was optimistic that future tests (with fully charged batteries) would yield better speed results. Final inspection was at this point satisfied. Further testing was required to satisfy the agreed upon design requirements.

5.8 SECOND MOTORIZED TRIAL

Location: Dalplex Pool
6260 South Street

Date: March 31st, 2005

Requirements:
The purpose of this testing session was to further satisfy the design requirements. The tests performed were:

- Speed testing with the array
- Speed testing without the array
- Stability
- Battery depletion
- Camera vision

The corresponding design requirements were:

- An effective speed of 4 knots without the array attached
- No speed requirement was set for the vessel when the array is attached
- It was required that the vessel be operable, without disruption, at a roll angle of 18 degrees. This again was not measured.
- The batteries needed to provide enough power for 2 hours at 75 % thrust.
- It was required that the camera visibility be unobstructed by the hull or any part thereof.

Apparatus:

- Full prototype without cover
- Tools
- ~120 lbs of concrete for ballast
- 1 – Truck (for transport)
- 1 – Dolly (for transport)

Methods:

The prototype was transported to the Dalplex pool using a truck and dolly. Once at the pool, the motors (bow and stern) were mounted, the vessel was placed in the water, the batteries were placed into the vessel, the proper electrical connections were made and the hydrophone array was assembled (refer to user's manual in the appendices). A rope was tied to the vessel for safety purposes. Figure 37 Second Test shows the robotic vessel in the pool with the hydrophone array attached.

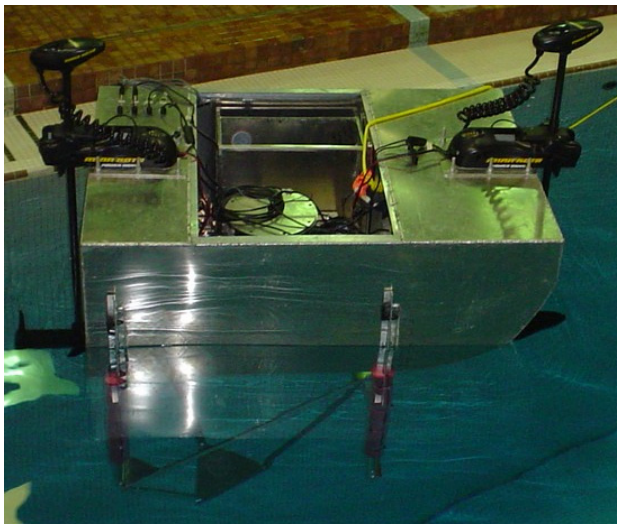


Figure 37 Second Test of Full Assembly

Speed trials were performed with and without the array in the same manner as in the previous round of testing. The operative roll angle again was not measured. The battery voltage was measured twice, once before and once after testing. Finally a small single lens camera was placed inside the electrical enclosure (pipe) to test the visibility.

The voltage (indicative to the battery capacity) had increased over a testing period of approximately an hour and a half.

Due to a temporary steering failure of the bow-mounted motor, the speed trials presented here (figure 38) are not representative of the full thrust capacity.

Results and Discussion:
The measured speed averaged ~2.6 knots, as shown in figure 38 without the array was. This was higher than in the first motorized trial (averaging ~2.3 knots). The top speed as defined in the design requirements is effectively 4 knots in calm water. The client is satisfied with the current top speed despite failing to meet this design requirement. Based on observation, the client is satisfied with the stability of the vessel. An interesting note is that the battery voltage had increased over the testing period (~1.5 hours). This indicates that the electrical loading over this time period was practically insignificant to the batteries. Based on this, it can be said that the batteries are more than able to meet the onboard energy requirements. The visibility of the single lens camera was unobstructed. However, this remains to be tested for the 3 lens stereo camera. The table below compares the requirements and results from all performed tests. The total weight of the vessel and ballast is 575lbs. The weight of the hull alone was found to be 160 lbs which is less than the maximum allowable weight of 200 lbs.

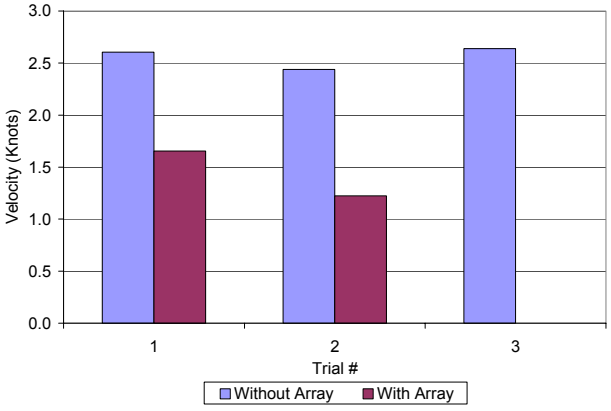


Figure 38 Measured Velocities in 2nd Round Testing

Table 4 - Design Requirements Comparison

Design Aspect	Design Requirement	Actual	Satisfied?
Speed without Array	Effectively 4 knots	2.61 knots	No – Client satisfied
Speed with Array	N/A	1.57 knots	N/A
Stability	Operate at 18° roll angle	Qualitative results	No data - Client satisfied
Maneuverability – Turning	Zero turning radius	Zero turning radius	Yes
Maneuverability – Control	2 DOF	3 DOF	Yes
Endurance Requirement	2 hours at 75% thrust	Batteries more than sufficient	Partly satisfied
Camera Visibility	Unobstructed by hull	Satisfied with single lens	Pending use of 3 lens stereo camera
Dimensional Requirements	72" x 48" x 38" L x W x H	60" x 42" x 24"	Yes
Hull Weight	<200 lbs	160 lbs	Yes
Battery Handling	Easily removable	Satisfied	Yes
Control System	Adaptable for Autonomous Control	Satisfied	Yes
Waterproofing	Waterproof electrical enclosure	Pipe electrical enclosure is waterproof	Partly satisfied

5.9 TESTS NOT PERFORMED

The only design requirement that was not tested for was that of measuring the roll angle. Water tightness of the cover has not yet been tested because it is still not complete.

6.0 COST ANALYSIS

Table 5 - Hull Construction Cost

Hull Construction Cost			
Component	**Material Description**	**Amount**	**Cost**
Frame Members	6061-T6 Equal Leg Aluminum Angles	70.5 ft	$54.67
	6061-T6 Channels	15.7 ft	$21.97
	6061-T6 1/8" x 4" Flatbar	12.5 ft	$20.21
Hull Plating	5052-H34 Aluminum Sheet - Mill Finish	97.42 ft²	$361.25
	5052-H32 Aluminum Sheet - Mill Finish	16 ft²	$183.09
Misc.	6061-T6 8" Sch. 40 Pipe	1	$63.95
	12 volt Bilge P/P and Fittings	1	$60.00
	Plexiglas	1	$20.00
	Gasket	1	$15.00
	Carrying Handle	4	$35.00
	Marine Epoxy Paint	2 gal	$70.00
	Metal Primer Paint	1 gal	$35.00
	Shop supplies, etc.		$75.00
		Sub Total:	$1,015.14
		HST	$152.27
		Total:	$1,167.42

Table 6 - Hydrophone Array Cost

Hydrophone Array Construction Cost			
Component	**Material Description**	**Amount**	**Cost**
Array Frame	6061-T6 Aluminum Round Rod	42.33 ft	$26.78
	Aluminum Hinge and Fasteners	2	$10.00
Hydrophone Mounting Plate	6061-T6 Aluminum Flat Bar	0.11 ft^2	$0.30
		Sub Total:	$37.08
		HST	$5.56
		Total:	$42.64

Table 7 - Electrical System Cost

Electrical System Construction Cost			
Component	**Material Description**	**Amount**	**Cost**
Electrical Equipment Frame	6061-T6 Equal Leg Aluminum Angle	33.8 ft	$6.51
	5052-H34 Aluminum Sheet - Mill Finish	2.48 ft²	$9.19
Box for Electrical Frame	6061-T6 Equal Leg Aluminum Angle	20.7 ft	$16.03
	5052-H34 Aluminum Sheet - Mill Finish	17.68 ft²	$65.51
	Hinge for cover	2	$2.00
	Gasket	2	$50.00
	Rubber Stops	4	$10.00
	Watertight Electrical Fitting	TBD	TBD
Frame for Camera and Gyro	6061-T6 Aluminum Square Bar	1.3 ft	$1.08
	5052-H34 Aluminum Sheet - Mill Finish	0.28 ft²	$1.59
Batteries	10-3199-6 Motomaster Nautilus Deep Cycle Battery 103 Amp Hr Capacity	4	$479.96
Battery Mounts	6061-T6 Aluminum Angle	13.5 ft	$15.67
	6061-T6 Aluminum Clip	8	$5.00
		Sub Total:	$662.54
		HST	$99.38
		Total:	$761.92

Table 8 - Propulsion System Cost

Propulsion System Construction Cost			
Component	**Material Description**	**Amount**	**Cost**
Motors	MinnKota 50 PD Trolling Motor	2	$960.00
Transom Mount	5052-H2 Aluminum Plate	1.40 ft^2	$55.31
	Miscellaneous Mounting Hardware	-	$10.00
		Sub Total:	$1,025.31
		HST	$153.80
		Total:	$1,179.11

Table 9 - Control System Cost

Control System Construction Cost			
Component	**Material Description**	**Amount**	**Cost**
Remote Control Unit	Multiple Channel RC Package	1	$500.00
	Miscellaneous Integration Components		$100.00
		Sub Total:	$600.00
		HST	$90.00
		Total:	$690.00

Table 10 - Total Budget Triton Robotics Anticipated

Total Budget	
Component	**Total Cost**
Hull	$1,015.14
Hydrophone Array	$37.08
Propulsion System	$1,025.31
Electrical System	$662.54
Control System	$600.00
Sub Total:	$3,340.07
HST (15%):	$501.01
Total Cost:	$3,841.08

Please note that the initial expected budget was $7,200.00. The expected cost we best estimated at $3,841.08. Our Client tabulated Triton Robotics has expensed $4,650.71 and is therefore approximately $2,549.29 under budget.

Please refer to *Appendix C – Detailed Bill of Materials* for detailed listings of all construction components.

Table 11 - Total Expenses

Total Expenses	
Component	**Total Cost**
Hull	$1,369.98
Hydrophone Array	N / A
Propulsion System	$1,782.50
Electrical System	$1,198.23
Control System	$300.00
Sub Total:	$3,953.11
HST (15%):	$697.60
Total Cost:	$4,650.71

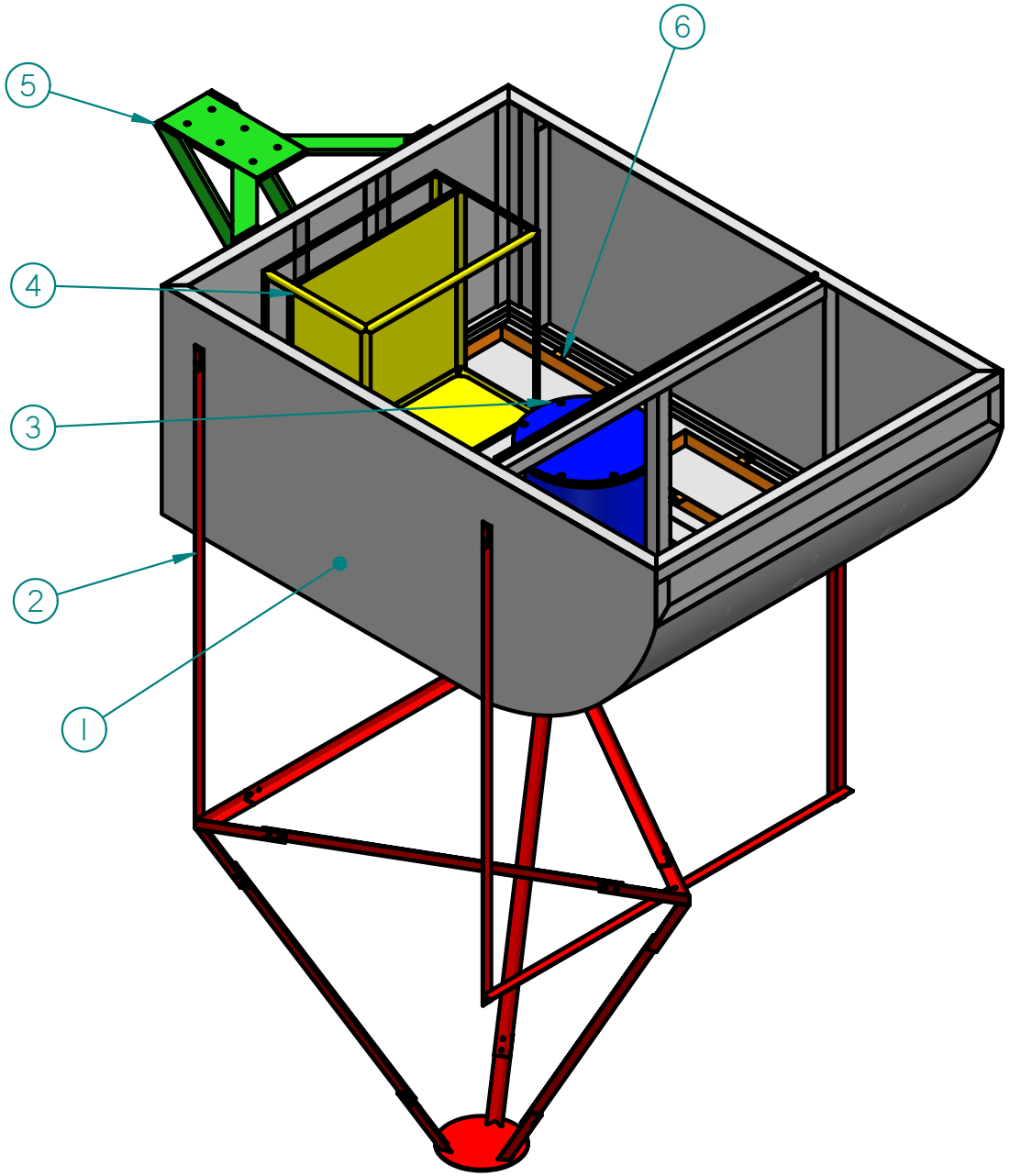
6.0 SUMMARY AND CONCLUSIONS

Triton Robotics is confident that all of the design requirements will be met to the client's satisfaction on or before the handover date. The anticipated handover date with our client is yet to be set, but it will be in late April, 2005. There are no roadblocks anticipated with delivering the completed vessel to the client.

6.1 PATH FORWARD

Based on the completion of the tasks that are outlined in the attached Gantt Chart the project is coming to a close. All group members will leave their contact information with the client for future questions and consulting. A documentation package including an owner's manual will be supplied to the client when the handover takes place; it has been included in this document in Appendix B, as requested.

APPENDIX A – DRAWINGS



ITEM	DESCRIPTION	QTY
1	HULL	1
2	ARRAY	1
3	VIEW PIPE	1
4	ELECTRICAL FRAME	1
5	MOTOR MOUNT	1
6	BATTERY MOUNT	4

TRITON ROBOTICS

Project: ROBOTIC VESSEL

Drawing: RV-000-00 GENERAL ARRANGEMENT

Unless Otherwise Noted:

Units : mm	Units : inches	Angles
x. xx +/- .15	x. xxx +/- .005	+/- 0.25 °
x. x +/- .25	x. xx +/- .01	
x +/- .50	x.x +/- .02	

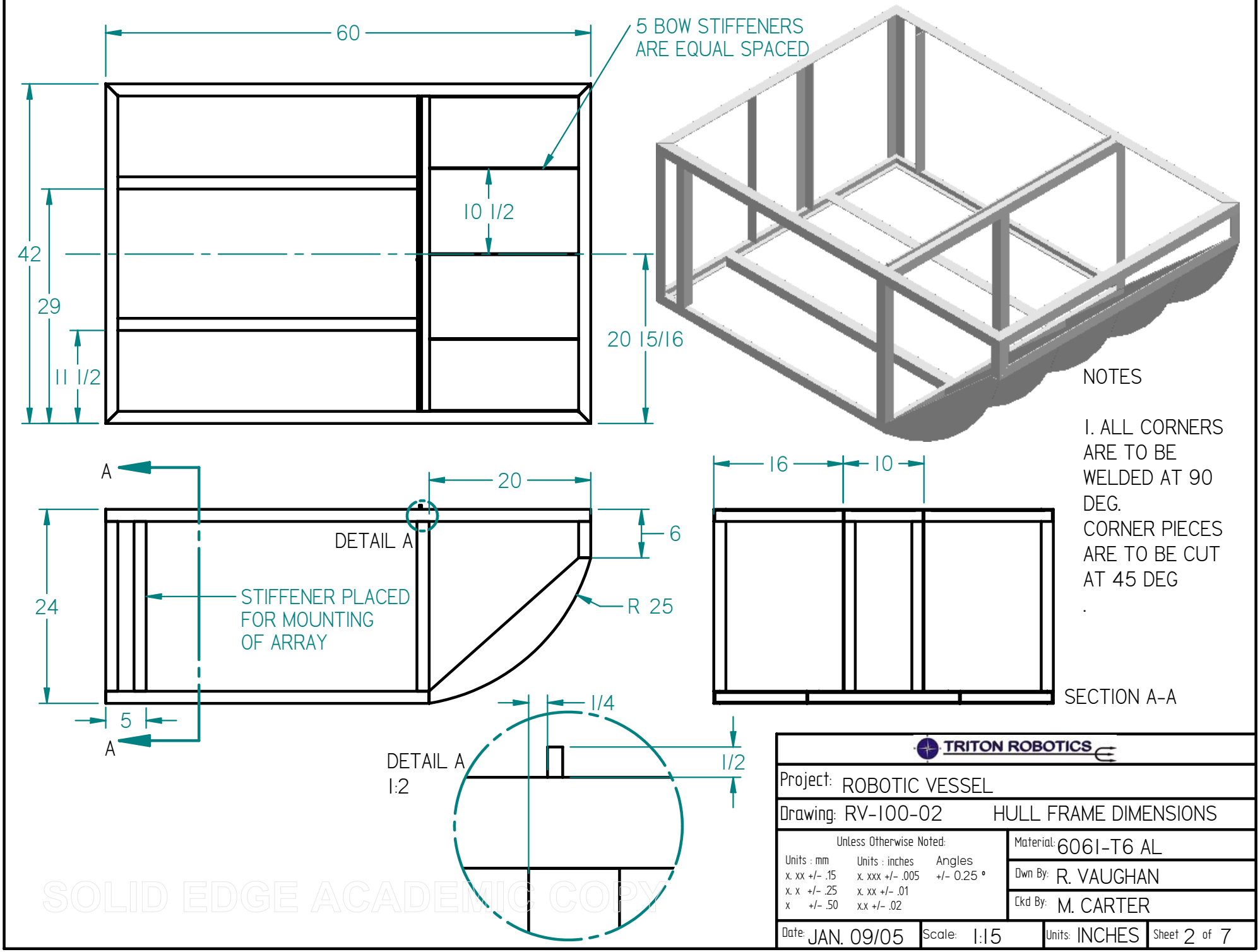
Material: Aluminum

Dwn By: J. Slaunwhite

Ckd By: A. MacFarlane

Date: JAN 13 /05 | Scale: NTS | Units: Inches | Sheet 1 of 1

SOLID EDGE ACADEMIC COPY



NOTES

1. ALL CORNERS ARE TO BE WELDED AT 90 DEG.
CORNER PIECES ARE TO BE CUT AT 45 DEG
.

SOLID EDGE ACADEMIC COPY

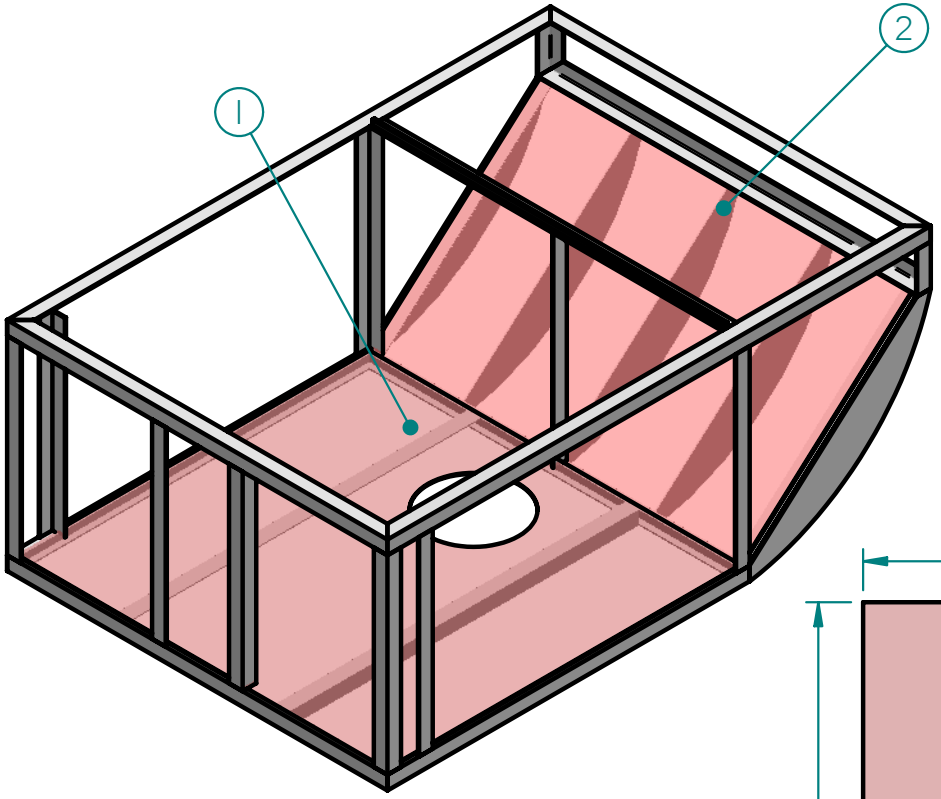
TRITON ROBOTICS

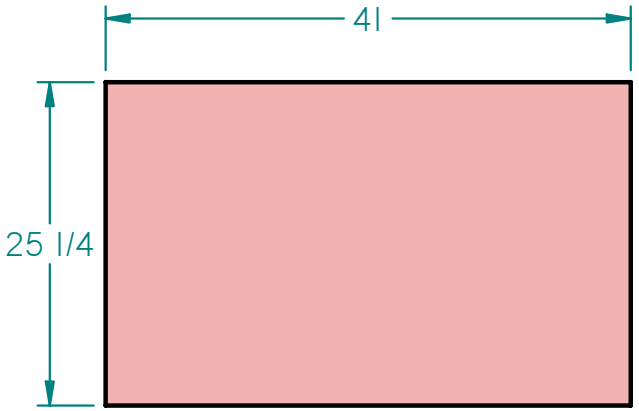
Project:	ROBOTIC VESSEL
Drawing:	RV-100-02 HULL FRAME DIMENSIONS

Unless Otherwise Noted:

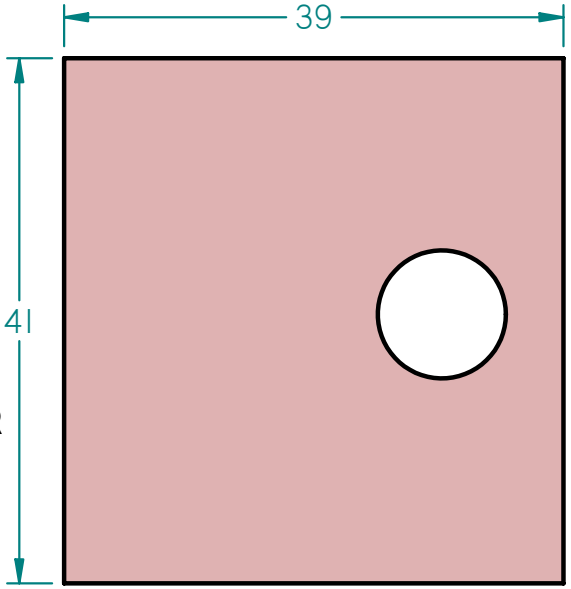
Units : mm	Units : inches	Angles
x. xx +/- .15	x. xxx +/- .005	+/- 0.25 °
x. x +/- .25	x. xx +/- .01	
x +/- .50	x.x +/- .02	

Material:	6061-T6 AL
Dwn By:	R. VAUGHAN
Ckd By:	M. CARTER
Date:	JAN. 09/05
Scale:	1:15
Units:	INCHES
Sheet	2 of 7





WATER TIGHT FLOOR-BOW
ITEM 2



WATER TIGHT FLOOR
ITEM 1

NOTES

1. POSITION OF VIEWPORT CAMERA HOLE ON ITEM 1 TO BE DETERMINED AFTER INSTALLATION OF WATER TIGHT FLOOR.

2. EXPANDABLE FOAM WILL BE INSERTED AFTER INSTALLATION OF WATER TIGHT FLOORS

ITEM	DECSRIPTION	QTY
1	0.081 THICK, 5052-H32, AL SHEET, WATER TIGHT FLOOR	1
2	0.081 THICK, 5052-H32, AL SHEET, WATER TIGHT FLOOR-BOW	1

SOLID EDGE ACADEMIC COPY

TRITON ROBOTICS

Project: ROBOTIC VESSEL

Drawing: RV-100-05 HULL FLOOR ARRANGEMENT

Unless Otherwise Noted:

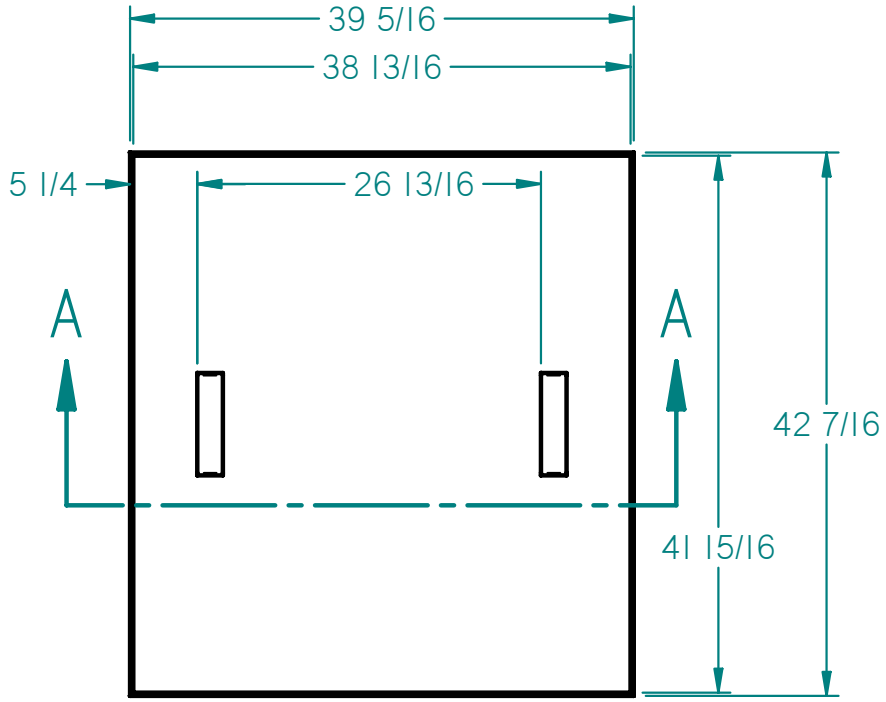
Units : mm	Units : inches	Angles
x. xx +/- .15	x. xxx +/- .005	+/- 0.25 °
x. x +/- .25	x. xx +/- .01	
x +/- .50	x.x +/- .02	

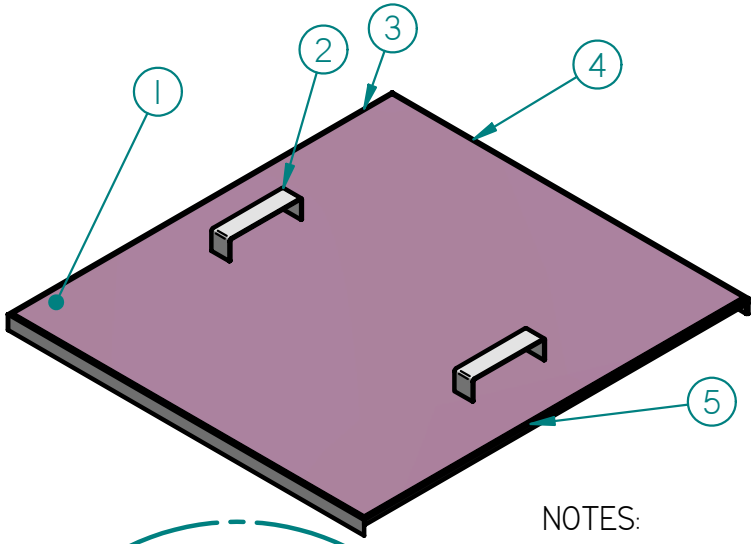
Material: 5052-H32 AL SHEET

Dwn By: R. VAUGHAN

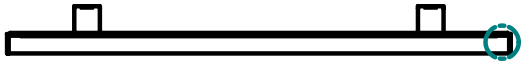
Ckd By: M. CARTER

Date: JAN. 11/05 | Scale: 1:15 | Units: INCHES | Sheet 5 of 7

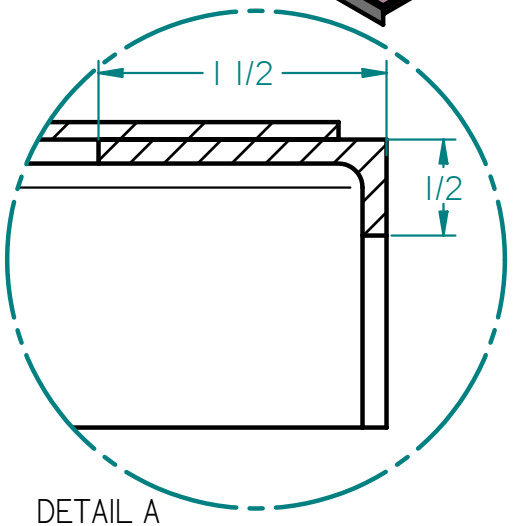




SECTION A - A



DETAIL A



DETAIL A
FRONT ANGLE
1:1

NOTES:

1. ITEM 5, TO BE CUT TO FIT.

2. ALL WELDS MUST BE CONTINUOUS AND WATER TIGHT.

3. TACO WEATHER SEAL TO BE INSTALLED INSIDE ANGLE.

4. ALL AL FRAME ENDS TO BE CUT AT 45 DEG.

ITEM	DESCRIPTION	QUANTITY
1	0.081 THICK, 5052-H32 AL SHEET	1
2	FABRICATED HANDLES	2
3	1 1/2 x 1 1/2 x 1/8, 6061-T6 AL ANGLE	1
4	1 1/2 x 1 1/2 x 1/8, 6061-T6 AL ANGLE	2
5	1 1/2 x 1/2 x 1/8, 6061-T6 AL ANGLE, SEE DETAIL A	1

SOLID EDGE ACADEMIC COPY

TRITON ROBOTICS

Project: ROBOTIC VESSEL

Drawing: RV-100-07 HULL COVER ARRANGEMENT

Unless Otherwise Noted:
Units : mm — x. xx +/- .15, x. x +/- .25, x +/- .50
Units : inches — x. xxx +/- .005, x. xx +/- .01, x.x +/- .02
Angles +/- 0.25 °

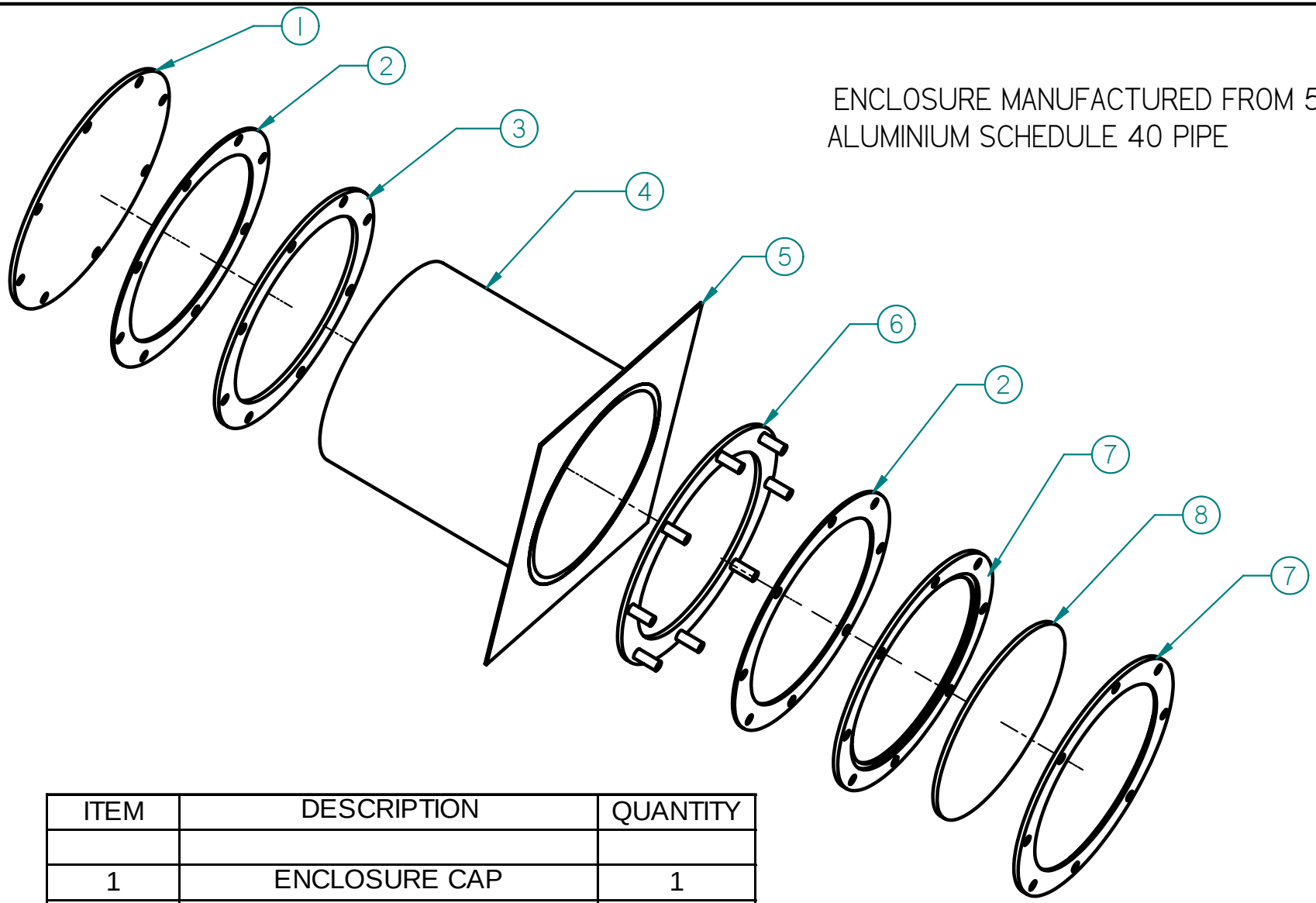
Material: SEE TABLE

Dwn By: R. VAUGHAN

Ckd By: M. CARTER

Date: JAN. 08/05 | Scale: 1 : 15 | Units: INCHES | Sheet 7 of 7

ENCLOSURE MANUFACTURED FROM 5052-H32
ALUMINIUM SCHEDULE 40 PIPE



ITEM	DESCRIPTION	QUANTITY
1	ENCLOSURE CAP	1
2	RUBBER GASKET	2
3	BOLTED FLANGE	1
4	10" NOMINAL PIPE	1
5	SHIP'S HULL	1
6	STUDDED FLANGE	1
7	PORTHOLE FLANGE	2
8	1/4" PLEXIGLASS	1

TRITON ROBOTICS

Project: ROBOTIC VESSEL

Drawing: RV-301-01 CAMERA ARRANGEMENT

Unless Otherwise Noted:

Units : mm	Units : inches	Angles
x. xx +/- .15	x. xxx +/- .005	+/- 0.25 °
x. x +/- .25	x. xx +/- .01	
x +/- .50	x.x +/- .02	

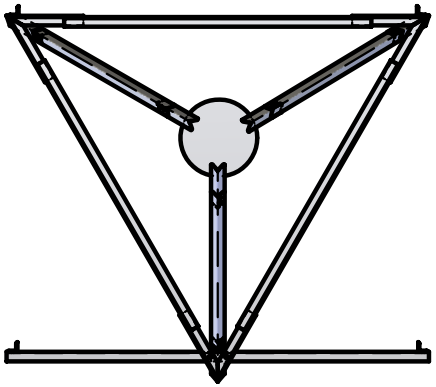
Material: ALUMINIUM

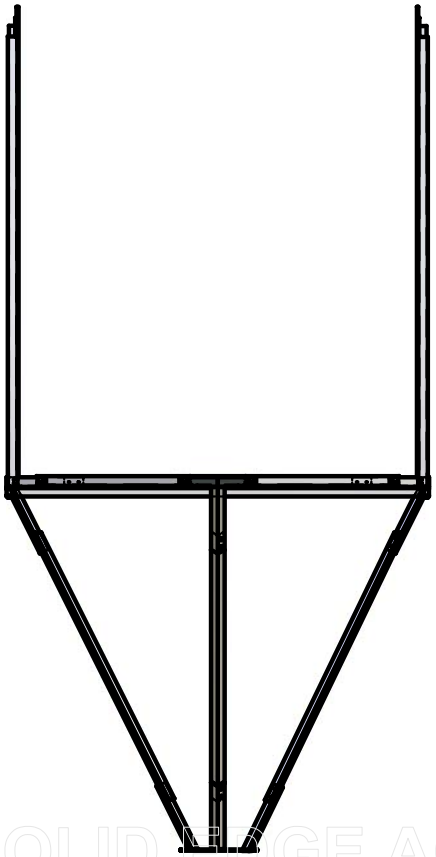
Dwn By: A. CALDWELL

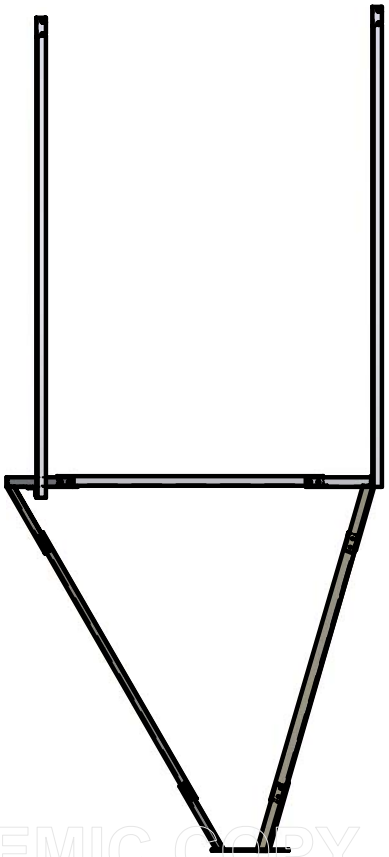
Ckd By: M.J. CARTER

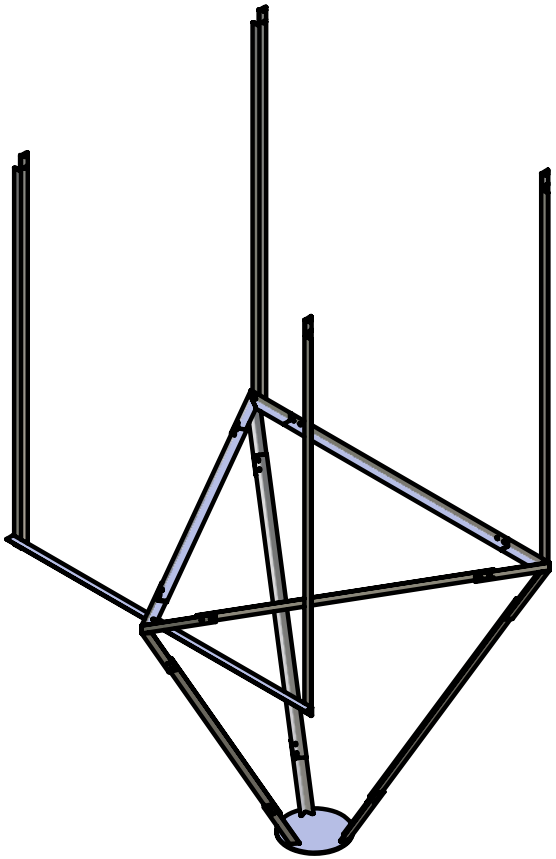
Date: Jan. 8, 05 | Scale: 1:7 | Units: Inches | Sheet 1 of 5

SOLID EDGE ACADEMIC COPY









SOLID EDGE ACADEMIC COPY

TRITON ROBOTICS

Project: ROBOTIC VESSEL

Drawing: RV-200-01 ARRAY -GENERAL ARRANGEMENT

Unless Otherwise Noted:

Units : mm	Units : inches	Angles
x. xx +/- .15	x. xxx +/- .005	+/- 0.25 °
x. x +/- .25	x. xx +/- .01	
x +/- .50	x.x +/- .02	

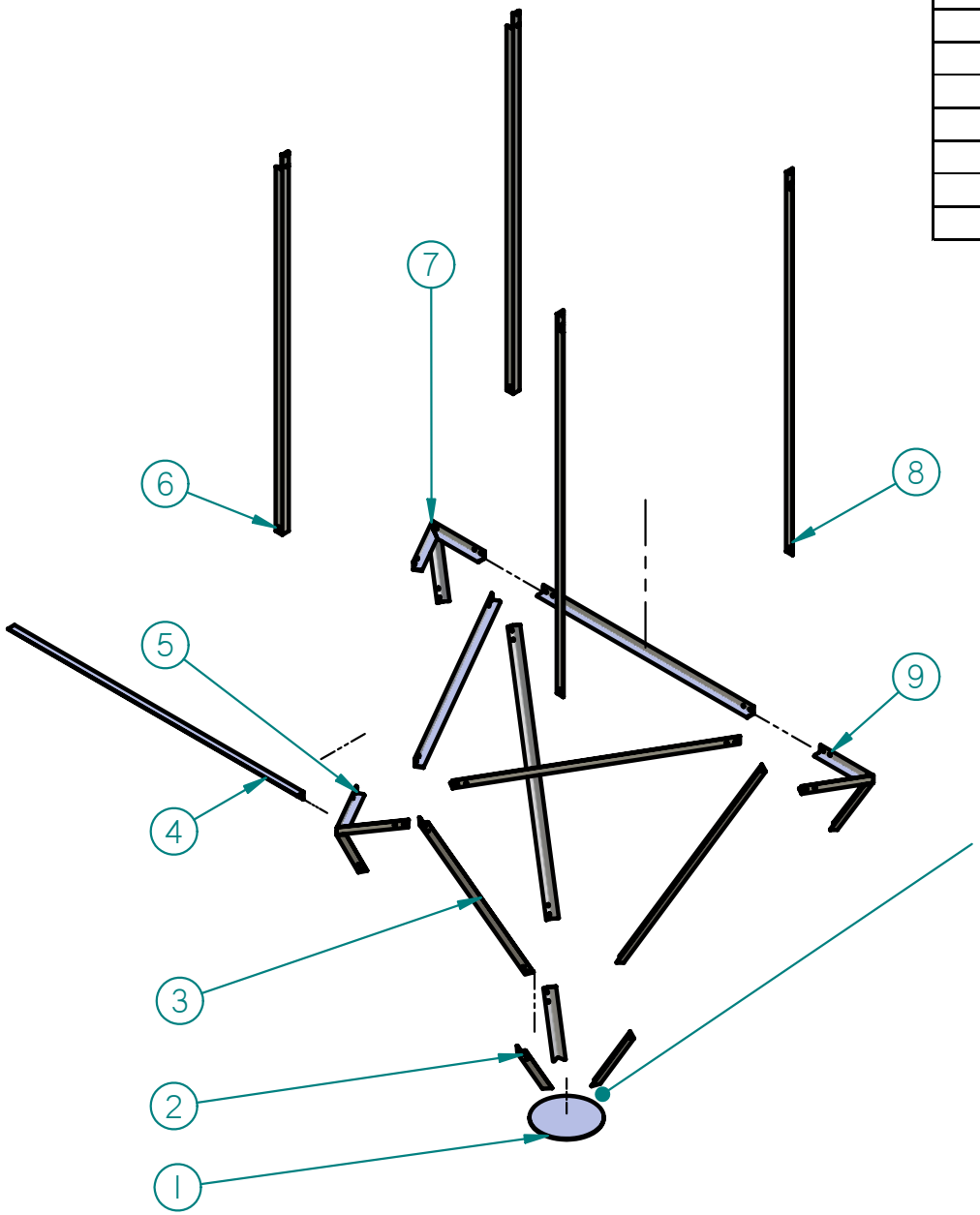
Material: ALUMINUM

Dwn By: J. SLAUNWHITE

Ckd By: R. VAUGHAN

Date: JAN. 12/05 | Scale: 1:20 | Units: INCHES | Sheet 1 of 16

ITEM	DRAWING	QTY
1	RV-200-14 ARRAY - BOTTOM PLATE	1
2	RV-200-12 ARRAY - LOWER ANGLE	3
3	RV-200-06 ARRAY - UPPER CONNECTING ANGLE	6
4	RV-200-13 ARRAY - CROSSBAR ANGLE	1
5	RV-200-05 ARRAY - FRONT CORNER	1
6	RV-200-16 ARRAY - LEFT UPRIGHTANGLE	2
7	RV-200-03 ARRAY - LEFT CORNER	1
8	RV-200-15 ARRAY - RIGHT UPRIGHT ANGLE	2
9	RV-200-04 ARRAY - RIGHT CORNER	1



NOTE: ALL CONECTIONS BOLTED UNLESS OTHERWISE STATED

3 ANGLES WELDED TO PLATE, POSITIONING TBD DURING ASSEMBLY

SOLID EDGE ACADEMIC COPY

TRITON ROBOTICS

Project: ROBOTIC VESSEL

Drawing: RV-200-02 ARRAY - EXPLODED VIEW

Unless Otherwise Noted:

Units : mm	Units : inches	Angles
x. xx +/- .15	x. xxx +/- .005	+/- 0.25 °
x. x +/- .25	x. xx +/- .01	
x +/- .50	x.x +/- .02	

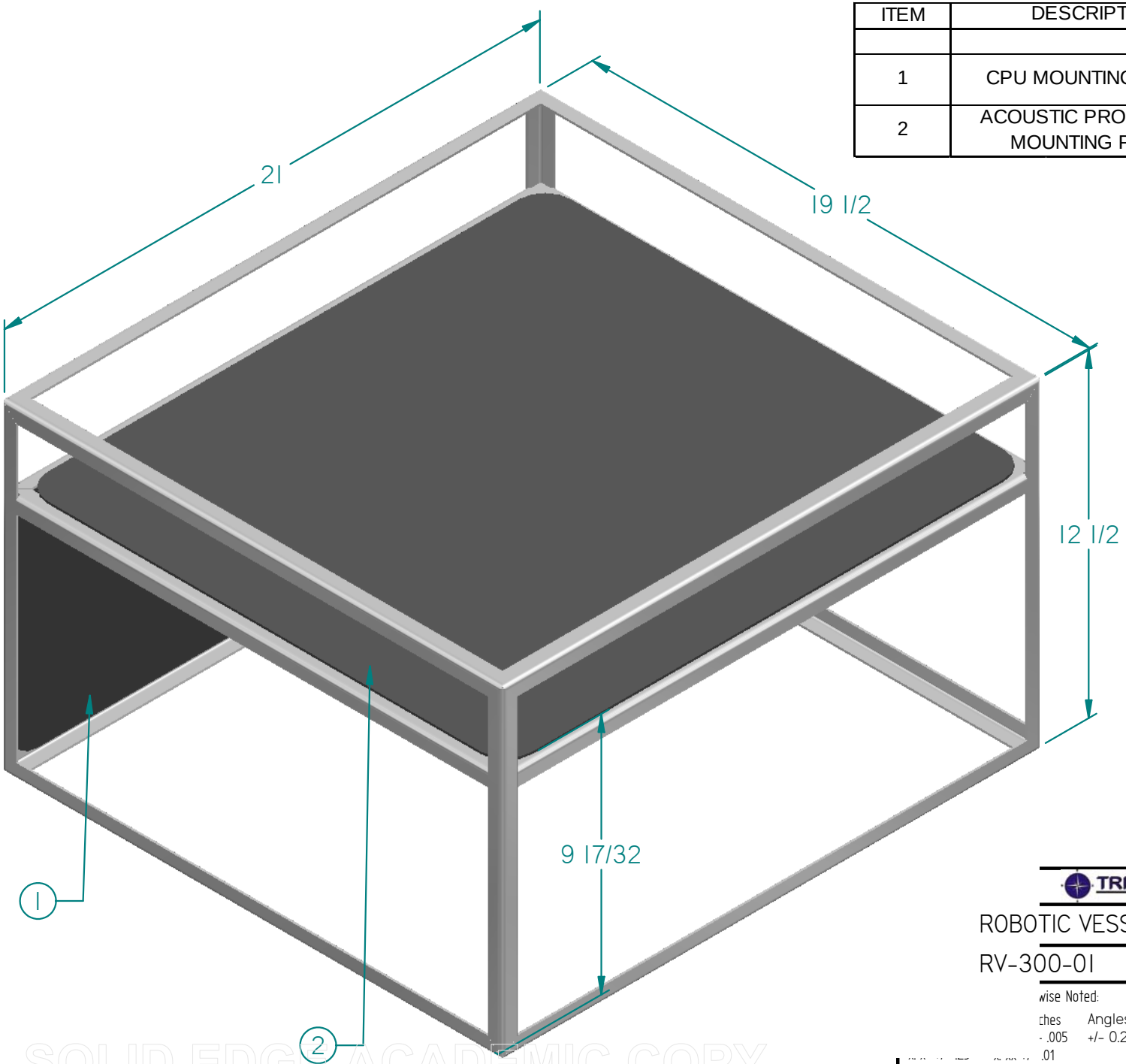
Material: ALUMINUM

Dwn By: J. SLAUNWHITE

Ckd By: R. VAUGHAN

Date: JAN. 12/05 | Scale: 1:20 | Units: INCHES | Sheet 2 of 16

ITEM	DESCRIPTION	DIM.	QTY
1	CPU MOUNTING PLATE	9"X20-1/2" X0.081"	1
2	ACOUSTIC PROCESSOR MOUNTING PLATE	19"X20-1/2" X0.081"	1



SOLID EDGE ACADEMIC COPY

TRITON ROBOTICS

ROBOTIC VESSEL

RV-300-01 ELECTRICAL ENCLOSURE

wise Noted:
ches Angles
.005 +/- 0.25 °
.01
x +/- .50 x.x +/- .02

Material: 5052-H32 AL

Dwn By: A. CALDWELL

Ckd By: M.J. CARTER

Date: Jan. 8, 05 | Scale: 1:4 | Units: Inches | Sheet 1 of 3

APPENDIX B –
OWNERS MANUAL

Triton Robotics
Robotic Vessel 2005

Owner's Manual

Table of Contents

1.0 Congratulations on Your New Robotic Vessel 4
2.0 Safety Legend 4
3.0 Your Robotic Vessel at a Glance 5
4.0 Important Safety Precautions 6
5.0 Your Robotic Vessels Safety Features 7
6.0 Before Operating – General Assembly Instructions 9
6.1 Mounting the Trolling Motors 9
6.2 Launching the Boat 10
6.3 Making the Electrical Connections 11
7.0 Remote Control Operation 11
8.0 Disassembly 13
9.0 Maintenance 13
10.0 Technical Information 15

Appendixes

Appendix A Minn Kota PD-50 Trolling Motor Instruction Manual
Appendix B Futaba 6 Channel Radio Control System Instruction Manual
Appendix C Blue Sea Systems DC Power Distribution Panel Instruction Manual

Table of Figures

Figure 1: Robotic Vessel External View 5
Figure 2: Robotic Vessel Internal View 5
Figure 3: Safety Features 7
Figure 4: Remote Controller 12

Owner Identification Information

OWNER _____

ADDRESS _____
STREET

_____ _____ _____
CITY PROVINCE POSTAL CODE

DELIVERY DATE _____

OWNERS SIGNATURE _____

TRITON ROBOTICS SIGNATURE _____

1.0 Congratulations on Your New Robotic Vessel

Congratulations! Your selection of a Triton Robotics 2005, Robotic Vessel was a wise investment. It will give you years of great remote boating pleasure.

One of the best ways to become familiar and enhance the enjoyment of your new robotic vessel is to read and continually refer back to this manual. In this document you will learn how to operate your robotic vessels driving controls and special features. After reading this manual, be sure to keep this document with your vessel so you can refer to it at any time.

Maintaining your vessel according to the information provided in this manual will help to keep your remote boating trouble-free while serving to preserve your investment.

2.0 Safety Legend

Your safety and the safety of others is very important. Therefore operating this vessel safely is an important responsibility.

To help you make informed decisions about safety, we have provided safe remote boating operating procedures in this manual. The visual aids are to alert you to potential hazards that could hurt yourself and others.

We recognize it is not practical or possible to warn you about all the hazards associated with the operating or maintaining your robotic vessel. It is the responsibility of the user to actively use their good judgment when operating or maintaining your robotic vessel.

You will find important safety information represented with these three safety symbols.

Red you will be KILLED or SERIOUSLY hurt if you don't follow the instructions

WARNING

Orange you can be KILLED or seriously hurt if you don't follow the instructions

CAUTION

Yellow you can be hurt if you don't follow the instructions

3.0 Your Robotic Vessel at a Glance

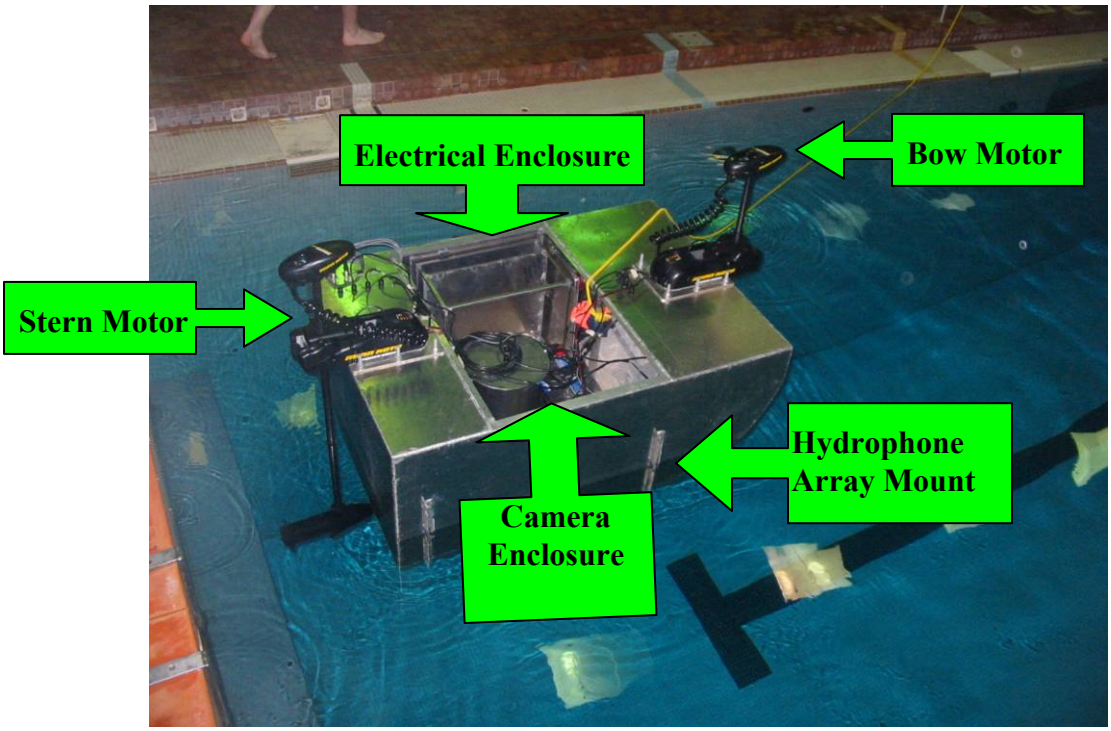


Figure 1: Robotic Vessel External View

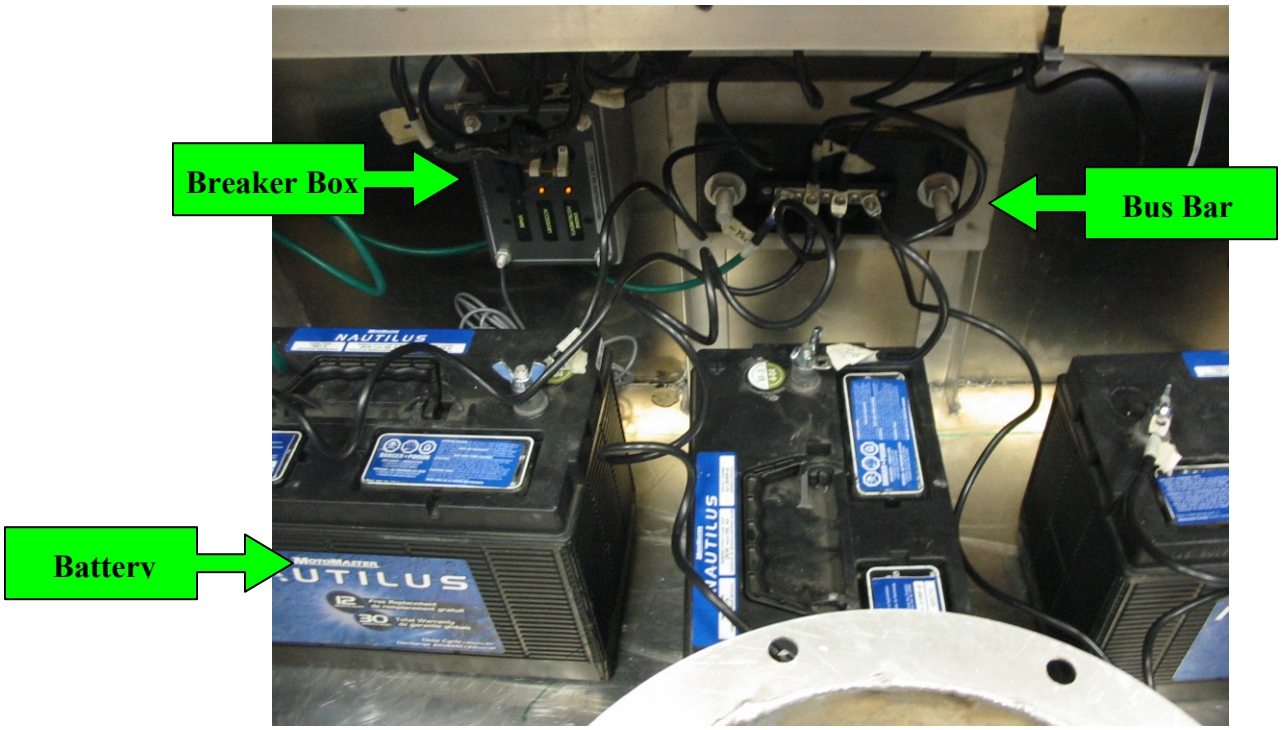


Figure 2: Robotic Vessel Internal View

4.0 Important Safety Precautions

Reading this manual you will find many safety recommendations throughout this section, and throughout this manual. The specified recommendations on this page are considered by Triton Robotics to be of the utmost importance.

Robotic Vessel is not for Passenger Transport
Your remote robotic vessel is under no circumstances be used to transport or support a person. The vessels hull is structurally strong enough to support the weight a person however, for their safety considerations people are to not use the vessel for personal transport.

Keep Swimmers Away from Operational Robotic Vessel
Efforts have been made by Triton Robotics to ensure that swimmers in close contact with the robotic vessel will not be in danger. However to avoid a potential dangerous situation swimmers are to be kept at a safe distance while the robotic vessel is under its own power.

Keep Children Away
Children are safest when they are not in close proximity of the robotic vessel. The acts of children are spontaneous and are impossible to account for, therefore for their personal safety they should never be in close proximity of the robotic vessel.

Control Your Speed
Excessive speed is a major factor in boating crashes and boating injuries. Generally the higher the speeds the greater the risk, but serious accidents can also occur at lower speeds. A remote robotic vessel does not have an extreme top speed but it does accelerate quickly and can surprise the operator. Never drive faster than is safe for the current conditions, regardless of the maximum speed posted.

Keep Your Robotic Vessel in a Safe Condition
Having a mechanical failure while the vessel is in operation in water can be extremely hazardous. To reduce the possibility of such problems visually inspect the vessel before each use and perform all regular maintenance outlined in this manual.

Don’t Drink and Boat
Alcohol and driving do not mix under any circumstances. Even one drink can reduce your ability to respond to changing conditions, and your reaction time gets worse with every additional drink. So don’t drink and boat, even if you are not the operator of the robotic vessel as your assistance may be required.

5.0 Your Robotic Vessels Safety Features

Your robotic vessel is equipped with many features that work together to protect the sensitive payload and any people in the surrounding area.

Some safety features do not require any action by the operator. A strong aluminum framework forms a safety cage around the cargo payload area of the hull and serves to protect it contents.

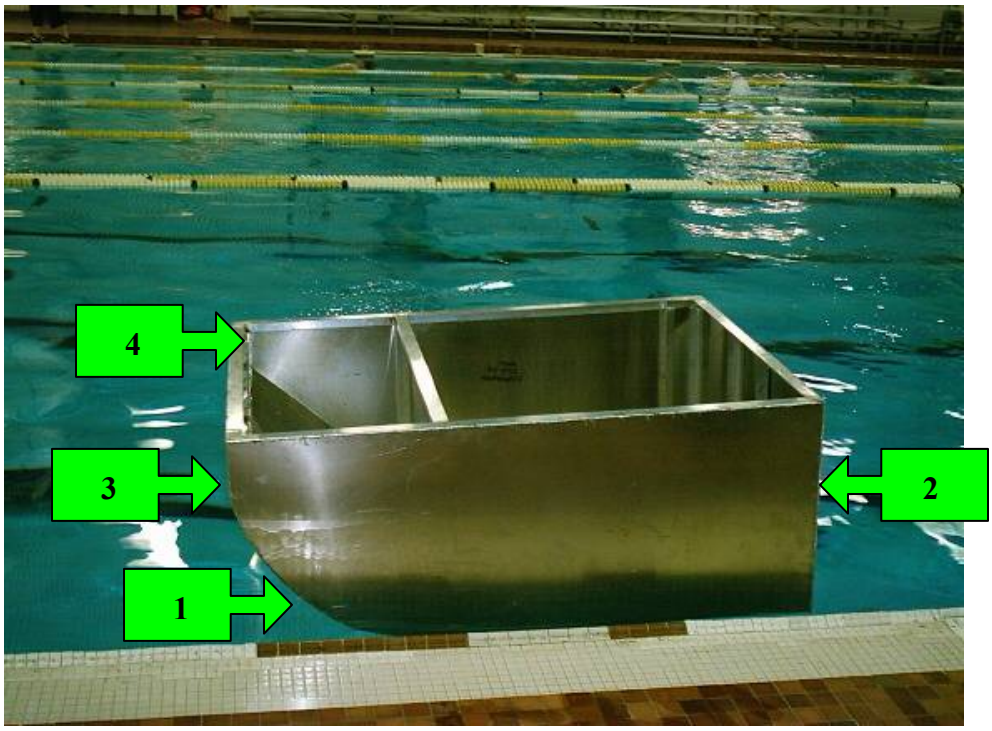


Figure 3: Safety Features

Safety Features Shown
- (1) Water tight inside floor
- (2) 24 inch deep hull
- (3) Curved Bow
- (4) Crash resistant hull

Safety Features Not Shown
- (5) Propeller Guards
- (6) Battery terminal bus bars
- (7) Electronic Breaker
- (8) Safety Kill Switch
- (9) Buoyant Foam

Propeller Cages

For your own safety and the safety of all people in the near vicinity of the two rotating propellers keep the propeller cages on at all times. It is only recommended that the propeller cages be removed to perform maintenance operations. In these circumstances motors must not be connected to any potential power source and extreme caution must be used to perform the maintenance required.

WARNING **Connection of Batteries to Bus Bar Terminals**

Extreme caution must be used in connecting batteries to the bus bar terminals. There is an individual bus bar for all positive connections of each of the four batteries as well as one for the negative connections. The person connecting the battery terminals to the bus bars must use extreme caution not to make any direct or indirect connection between the positive and negative terminals on the batteries as well as on the bus bars located on the hulls interior stern wall.

CAUTION **Transporting and Placing Batteries**

Be sure that when it comes time to transport or have contact with the batteries that your hands and arms are not wet. It is a known fact that water and electricity do not mix, your 12 volt batteries are no different, therefore use caution when transporting or placing the batteries.

6.0 Before Operating – General Assembly Instructions

It is extremely important that all assembly instructions be followed in the order they are presented here.

6.1 Mounting the Trolling Motors

The trolling motors should be mounted when the hull is on stable land.

Rear Motor:

1. Ensure motor shaft is in the locked horizontal position.
2. Place the trolling motor so that the 6 mounting bolts attached to the hull slide into the holes drilled into the mounting plate attached to the motor.
3. Install flat and lock washers and tighten nuts to the mounting bolts using a ¾" (19 mm) lug wrench.
4. Unlock the rear motor shaft by pulling the Grip Glide™ lever back and sliding the shaft of the motor forward. DO NOT fully lower the shaft into the vertical position so that the propeller is resting on the floor. This step is simply to ensure the rear motor shaft can be moved out of the way when the front motor is being installed.
5. Connect the positive motor lead, labeled "**Lead – Pos**", to the wire connected to the top of the hull labeled "**Motor – Pos".**
6. Wrap the connection with electrical tape so that no metal is exposed.
7. Connect the negative motor lead, labeled "**Lead – Neg**" to the wire connected to the top of the hull labeled "**Motor – Neg**".
8. Wrap the connection with electrical tape so that no metal is exposed.
9. Plug the 7 pin male connector from the motor into the 7 pin female connector attached to the top of the hull.
10. Connect the 9 pin female wire from the control box labeled "**Rear Control - F**" to the 9 pin male connector mounted through the hull near the rear of the vessel labeled "**Rear Control – M**".

Front Motor:

1. Ensure motor shaft is in the locked horizontal position.
2. Place the trolling motor so that the 6 mounting bolts attached to the hull slide into the holes drilled into the mounting plate attached to the motor.
3. Install flat and lock washers and tighten nuts to the mounting bolts using a ¾" (19 mm) lug wrench.
4. Connect the positive motor lead, labeled "**Lead – Pos**", to the wire connected to the top of the hull labeled "**Motor – Pos".**
5. Wrap the connection with electrical tape so that no metal is exposed.

6. Connect the negative motor lead, labeled "**Lead – Neg**" to the wire connected to the top of the hull labeled "**Motor – Neg**".
7. Wrap the connection with electrical tape so that no metal is exposed.
8. Plug the 7 pin male connector from the motor into the 7 pin female connector attached to the top of the hull.
9. Connect the 9 pin female wire from the control box labeled "**Front Control - F**" to the 9 pin male connector mounted through the hull near the front of the vessel labeled "**Front Control – M**".
10. Connect the grey wire labeled "**Kill Switch**" which is connected to the breaker box at the rear of the vessel to slot #6 labeled "**Kill Switch**" in the Futaba receiver pack which is located in the control box.
11. Connect the control battery pack wire into slot #1 labeled "**Battery**" in the Futaba receiver pack and turn the attached switch to the ON position. The breaker can now be switched on and off using the remote control.
12. Test the controls by hitting the kill switch on the remote control. If the breaker position does not change, check the control connections and try again.

WARNING **If the breaker position cannot be changed using the remote control, do not continue.**

13. If the breaker position CAN be changed using the remote control, ensure that the breaker is in the OFF position and continue on to **2.0 Launching the Boat**.

6.2 Launching the Boat

With both motor shafts in the horizontal position, slowly slide the boat into the water NOSE FIRST.

Once in the water, secure the boat to land using a tether line.

Lower the motor shafts into the vertical position by pulling back on the Grip Glide™ lever and sliding the shafts forward while letting them rotate downwards.

WARNING **Make sure that all battery terminals are equipped with their covers.**

While using proper lifting procedures, lower all 4 batteries into their positions and secure them using the bungee cords provided. DO NOT remove the terminal covers.

Lower the frame containing the electrical equipment into the electrical box. Ensure that the fan side of the computer is facing the open side of the box and that all electrical cords exit unrestricted through the back.

6.3 Making the Electrical Connections

Use extreme caution when working with the electrical connections. Ensure that the breaker is in the off position before you begin.

The electrical system operates on a 12 volt system. This does not imply the system cannot injure you. There is the potential for high current flows in the circuit capable of delivering large amounts of energy. Exposure to this energy could cause severe burns.

There are two circuits within the vessel: the **Motor Circuit** and the **Electronics Circuit**.

Motor Circuit:

1. Connect the "Pos-1" wire from the positive bus bar to the positive terminal of battery #1.
2. Connect the "Pos-2" wire from the positive bus bar to the positive terminal of battery #2.
3. Connect the "Pos-3" wire from the positive bus bar to the positive terminal of battery #3.
4. Connect the "Neg-1" wire from the negative bus bar to the negative terminal of battery #1.

The circuit is now live as indicated by the lights on the breaker box.

5. Connect the "Neg-2" wire from the negative bus bar to the negative terminal of battery #2.
6. Connect the "Neg-3" wire from the negative bus bar to the negative terminal of battery #3.

Electronics Circuit:
[This circuit is not yet functioning.]

Tightly secure the top hatch to the vessel before beginning operation.

7.0 Remote Control Operation

The remote control unit for your robotic vessel is a complicated unit. The remote controller shown in figure 4 operates both the variable control speed controllers and the directional controllers of the robotic vessel. The robotic vessel has both a bow and stern motor that are able to operate independently for better steering and speed control.

As shown in figure 4 below, the left controller stick operates the stern motor and the left stick operates the bow motor. Independent thrust control is achieved by moving the stick in the vertical direction, lowest being off and highest being maximum thrust for each

motor. For your convenience, the throttle control remains at the position you leave it. To steer your robotic vessel, move the stick in the horizontal direction to the left or right. This motion causes the appropriate motor to rotate, (right for clockwise, left for counter clockwise), until the stick is released.

CAUTION

The motors <u>will not</u> return to the neutral position automatically. With the controller you must reposition the motors to follow a straight path.

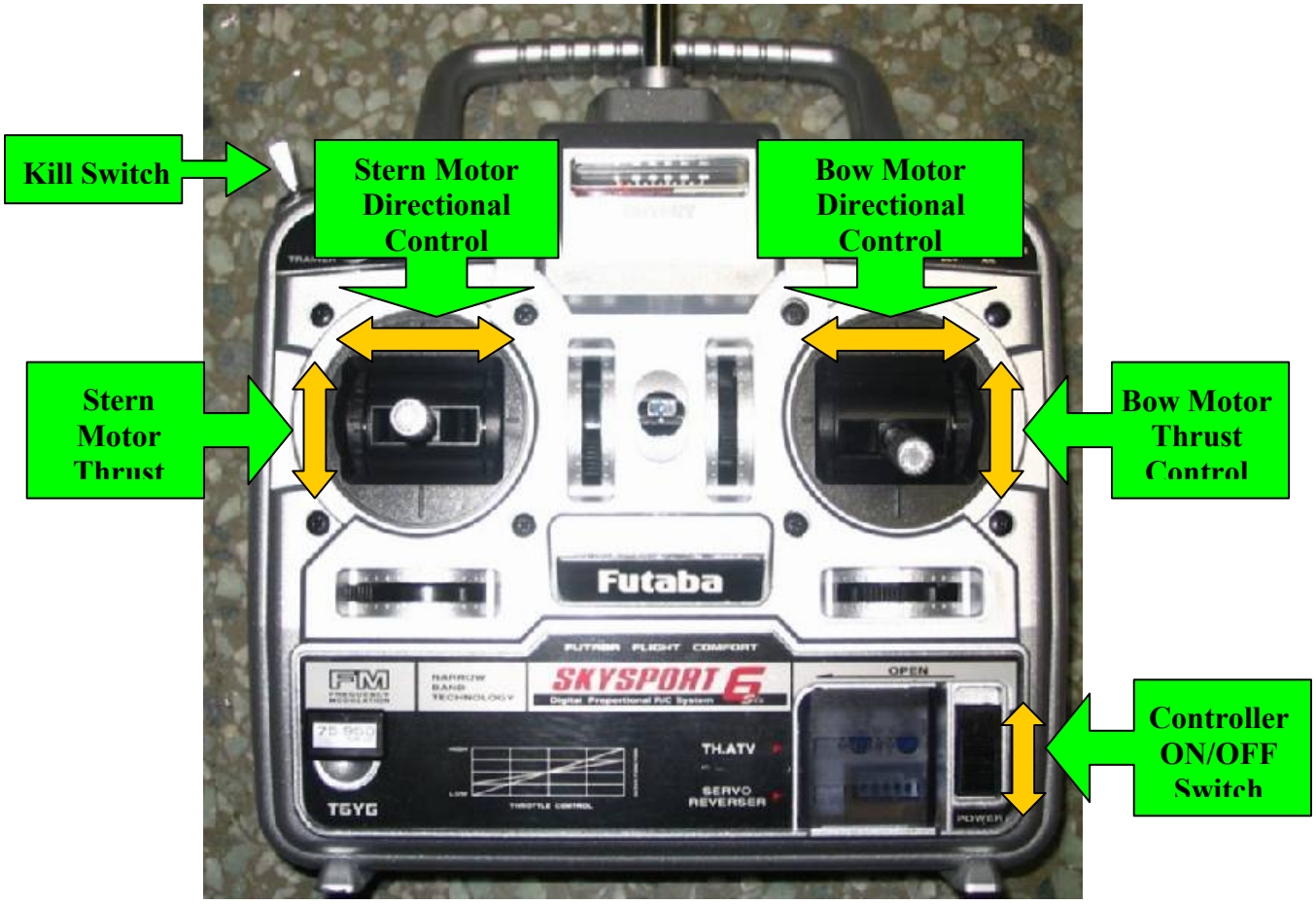


Figure 4: Remote Controller

Your robotic vessel has superb maneuverability and with various propulsion motor orientations you can move in any direction on the water surface with not much more than its own footprint required for turning.

Note that the remote control is equipped with a kill switch. Do not hesitate to use this switch as it was designed with safety considerations in mind. If the automatic kill switch is used it can simply be turned back on by flicking the switch back to its original position, when it is safe to do so.

It is suggested that the inexperienced driver begin at low speeds gradually increasing as controllability becomes more comfortable. With some practice you will soon master the control of your robotic vessel expanding the domain of aquatic exploration.

8.0 Disassembly

1. De-energize the motors by activating the remote kill switch.
2. Disconnect the “Neg-3” wire from the negative terminal of battery #3.
3. Disconnect the “Neg-2” wire from the negative terminal of battery #2.
4. Disconnect the “Neg-1” wire from the negative terminal of battery #1.

The circuit should now be de-energized - check lights on the breakers.

5. Disconnect the “Pos-3” wire from the positive terminal of battery #3.
6. Disconnect the “Pos-2” wire from the positive terminal of battery #2.
7. Disconnect the “Pos-1” wire from the positive terminal of battery #1.
8. Remove batteries from the vessel ensuring the terminal covers are in place.
9. Remove vessel from the water; take care to ensure props are positioned above the water line to avoid damage on removal.
10. Using a ¾” lug wrench, remove the nuts from the motor mounts and lift the motors from the vessel.
11. Safely stow all equipment and ensure the top hatch is securely affixed to the vessel.

9.0 Maintenance

Regularly maintaining your robotic vessel is the best way to protect your investment. Proper maintenance is essential to your safety and the safety of those in the operating vicinity of the vessel.

This section includes instructions for simple maintenance tasks, such as battery handling and motor service. Any maintenance issues that are not detailed in this section should be performed by a qualified technician.

Some of the most important safety precautions are outlined in this document. However, we cannot warn you of every conceivable hazard that can arise in performing maintenance. Only you can decide whether or not you should perform a given task.

WARNING **Failure to properly follow maintenance instructions and precautions can cause you to be seriously hurt or killed.**

Important Safety Precautions
Before you begin any maintenance make sure your robotic vessel is out of the water and in a suitable work area.

Notes: To reduce the possibility of fire or explosion, be careful when working around batteries. Always use a commercially available part cleaner to clean parts. Keep cigarettes, sparks and flames away from the batteries.

You should wear proper eye protection and protective clothing when working near batteries or when using compressed air.

Batteries

Check all battery terminals for corrosion (a white or yellowish powder). To remove this powder, cover the terminals with a solution of baking soda and water. The solution will bubble and turn brown. Wash away this new solution with clean water and wipe the terminals clean with a dry towel.

Check battery Specific Gravity at least every 3 months with a hydrometer and recharge if the battery SG reaches 1.240.

Store the batteries in an unheated dry area; the colder the area, the slower the rate of discharge.

CAUTION **Battery terminals and related accessories contain lead and lead compounds. Wash hands immediately after handling.**

To connect a battery be sure to have placed it in the battery mount before attempting to connect it. Always connect the positive terminal to the positive bus bar first. When disconnecting batteries always disconnect the negative cable first and reconnect it last.

Clean the battery terminal with a common terminal cleaning tool or wire brush, if no powder is present. Reconnect and tighten the cables, then coat the terminals with grease.

When it comes time to charge the batteries, remove all batteries from the robotic vessels hull. This will prevent damage to the vessels electrical system. Again, always disconnect the negative cable first and reconnect it last, even to the charger!

WARNING **Batteries contain explosive hydrogen gas. A spark of flame can cause the battery to explode with enough force to kill or seriously hurt you.**
Wear protective clothing and eye protection while performing battery maintenance.

Motors

DANGER **Disconnect all sources of power to trolling motors before attempting any maintenance including removing propeller cages.**

Minn Kota PD-50 Trolling Motors are designed to be completely maintenance free for users. Please consult the user manual that was supplied with the two motors if more information is required (see Appendix A).

Motor Mounts

The motor mounting bolts should be kept lightly lubricated with an anti seize compound or good quality grease to prevent thread galling and possible seizure of the aluminum nuts.

Camera View port

Make sure the hull of your robotic vessel is completely out of the water before attempting to remove the camera view port bolts. Bolts may have become seized and difficult to remove over time. If this occurs apply a commercially available lubricant to the bolt threads.

Use caution when removing the view port cover because there are gaskets that are delicate and must be treated with care.

When reassembling view port bolts be sure not to over tighten bolts because bolts are threading into aluminum threads that can be damaged.

Electrical System

Other than battery maintenance no special maintenance is required for the 12 V electrical system.

Hull

The hull of your robotic vessel should be completely water tight and mainly maintenance free. If any water is found to be leaking inside the hull consult a certified aluminum welder.

10.0 Technical Information

Hull

Overall Dimensions:	Length Overall:	60 inches
	Beam:	42 inches
	Moulded Depth:	24 inches
Total Hull Weight (Including Cover):		160 lbs
Operating Displacement:		575 lbs

Operating Draft at 575 lbs Displacement:	7 ¾ inches
Hull, Deck, Floor and Cover Plating:	5052-H32, 0.081 inch thick aluminum sheet
Framing Members:	1 ½ x 1 ½ x 1/8, 6061-T6 aluminum angle and 1 ½ x ¾ x 5/32 , 6061-T6 aluminum channel
Motor Mounting Bolts:	1/2 – 13 x 2 ½, 2024-T4 aluminum bolt
Viewing Port Outer Flange Bolts:	1/2 - 20 x 1, Grade 5 SS bolt

Array

Overall Dimensions:	Assembled Height:	81 inches
	Assembled Length:	40 inches
	Assembled Width:	45 inches
Framing Members:		1 x 1 x 1/8, 6061-T6 aluminum angle
Connector Bolts:		¼- 20 x ¾, 2024-T4 aluminum bolt

Motors

2 x Minn Kota Model PD 50	Maximum Amp Draw:	42
	Operating Voltage:	12 volts
	Variable Speed Control:	Forward only
	Prop:	Weedless Wedge 2
	Shaft:	54 inches long
	Rated Thrust:	50 lbs
Forward Motor:	Serial #: WWAF0013578	
Aft Motor:	Serial #: WWAF0013580	

Batteries

4 x Motomaster-Nautilus	Product #:		10-3199-6
	Marine Cranking Amps:		750 A
	Reserve Capacity/Amp Hour:		205 min/115 AH
	Weight:		60 lbs
	Serial #'s:	4851739	481752
		4851741	481748

DC Power Distribution Panel

Blue Sea Systems	Part Number:	8085
	Amperage Rating:	100 Amps continuous current
	Circuit Breakers:	2 x Blue Sea, C series 50 Amp breakers

DC Power Fuse Block

Blue Sea Systems	Amperage Rating:	60 Amp fuse block

Remote Control

Futaba Skysport 6, FM, Digital Proportional R/C System	Transmitter:	Model T6YG
	Transmitting Frequency:	79.950 MHz
	Channels:	6
	FCC ID:	AZPT6YG-72
	Receiver:	Model FP-R127DF
	Channels:	7
	FCC ID:	AZP-FP-R127DF-75

6 CHANNEL RADIO CONTROL SYSTEM

SKYSPORT 6 Six

6YG-FM

INSTRUCTION MANUAL

1M23N04606
FUTZ8562

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CE

Futaba®
Digital Proportional R/C System

Futaba®
Digital Proportional R/C System

Thank you for purchasing a Futaba 6YG. Before using your 6YG, read this manual carefully and use your R/C set safely. After reading this manual, store it in a safe place.

See the glossary page 22 for a definition of the special terms used in this manual.

APPLICATION, EXPORT, AND RECONSTRUCTION

1. This product may be used for model airplane or surface use if on the correct frequency.

2. Exportation precautions
   (a) When this product is exported from Japan, its use is to be approved by the Radio Law of the country of destination.
   (b) Use of this product with other than models may be restricted by Export and Trade Control Regulations. An application for export approval must be submitted.

3. Modification, adjustment, and replacement of parts
Futaba is not responsible for unauthorized modification, adjustment, and replacement of parts of this product.

The Following Statement Applies to the Receiver (for U.S.A.)

This device complies with part 15 of the FCC rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference, and
(2) This device must accept any interference received, including interference that may cause undesired operation.

•No part of this manual may be reproduced in any form without prior permission.
•The contents of this manual are subject to change without prior notice.
•This manual has been carefully written. Please write to Futaba if you feel that any corrections or clarifications should be made.
•Futaba is not responsible for the misuse of this product.

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SAFETY INFORMATION

To ensure safe use, observe the following precautions.

Meaning of Special Markings

Pay special attention to safety at the parts of this manual that are indicated by the following marks.

Mark	Meaning
⚠DANGER	Procedures which may lead to a dangerous condition and cause death or serious injury to the user if not carried out properly.
⚠WARNING	Procedures which may lead to a dangerous condition or cause death or serious injury to the user if not carried out properly, or procedures where the probability of superficial injury or physical damage is high.
⚠CAUTION	Procedures where the possibility of serious injury to the user is small, but there is a danger of injury, or physical damage, if not carried out properly.

Symbol:

Prohibited Mandatory

Precautions During Flight

⚠WARNING

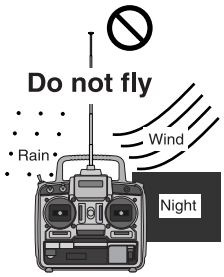
Do not fly or turn "On" simultaneously on the same frequency.

Interference will cause a crash.

Use of the same frequency will cause interference even if the modulation method (AM, FM, PCM) is different.

Do not fly on rainy or windy days, or at night.

Water will penetrate into the transmitter (Tx) and cause faulty operation, or loss of control, and cause a crash.



Do not fly in the following places:

-Near other R/C flying fields (within about 2.5miles [3km]

-Near people on the ground, or objects in the air

-Near homes, schools, hospitals, or other places where there are a lot of people

-Near high tension lines, high structures, or communication facilities

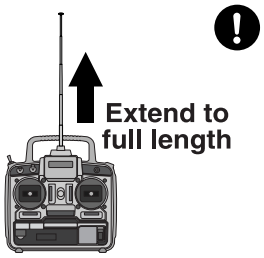
Radiowave interference and obstructions may cause a crash. A crash caused by trouble in the R/C set, or the model itself, may cause death or property damage.

Do not fly when you are tired, sick, or intoxicated.

Fatigue, illness, or intoxication will cause a loss of concentration or normal judgment and result in operation errors and a crash.

Extend the antenna to its full length.

If the antenna is shortened, the effective range of the radio signal will be shorter.



Always test the R/C set before use.

Any abnormality in the R/C set, or model, may cause a crash.

Before starting the engine, check that the direction of operation of each servo matches the operation of its control stick. If a servo does not move in the proper direction, or operation is abnormal, do not fly the plane.

Check that the transmitter (Tx) antenna is not loose.

If the transmitter antenna comes off during use, control will be lost and the model will crash.

⚠CAUTION

When placing the transmitter (Tx) on the ground during flight preparations, be sure that the wind cannot knock it over.

If it is knocked over, the throttle stick may be pushed to full throttle, the engine will speed up and create a very dangerous situation.

Do not touch the engine, motor, or FET amp (speed control) during and immediately after use.

They are hot and will cause a burn.

Turning on the power switch:

Set the transmitter (Tx) throttle stick to idle.

1. Turn "On" the transmitter (Tx) power switch,

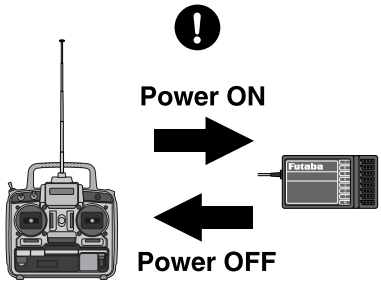
2. Then turn "On" the receiver (Rx) power switch.

Turning off the power switch:

Stop the engine,

1. Turn "Off" the receiver (Rx) power switch,

2. Then turn "Off" the transmitter (Tx) power switch.



If the Tx power switch is turned off first, the engine may go to full throttle unexpectedly and cause an injury.

Idle: The stick direction in which the engine or motor runs at the slowest speed. (usually the down position)

When adjusting the R/C set, always stop the engine.

If the engine suddenly goes to full throttle, it may cause an injury.

Nicd Battery Charging Precautions

⚠WARNING

Always charge the nicd batteries before each flight.

If the battery goes dead during flight, the plane may crash or fly away.

Charge the R/C nicd battery with the standard charger, or fast field charger. (sold separately)

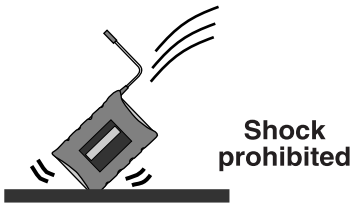
Overcharging may cause burns, fire, injury, blindness, etc. due to overheating, breakage, electrolyte leakage, etc.

Do not short the nicd battery connector terminals.

Shorting the terminals will cause sparking and overheating and result in burns or fire.

Do not drop or apply strong shock to nicd battery.

The battery may short out and cause overheating or breakage and electrolyte leakage and result in burns or damage from chemical contents.



Storage and Disposal Precautions

⚠WARNING

Do not leave the R/C set, battery, model airplane, etc. within the reach of small children.

Touching and operating the R/C set, or licking the battery, may cause injury or damage due to chemical content.

Do not throw the nicd battery into a fire or heat the nicd battery. Also, do not disassemble or rebuild the nicd battery.

Breakage, overheating, and electrolyte leakage may cause injury, burns, or blindness.

Nicd Battery Electrolyte

The electrolyte in a nicd battery is a strong alkali and can cause blindness if it gets in the eyes. If you get the electrolyte in your eyes, immediately wash your eyes with water and see a doctor. If you get the electrolyte on your skin or clothes, it may cause a burn. Immediately wash it off with water.

⚠CAUTION

Do not store the R/C set in the following places:

-Where it is very hot (75°F [40C] or more) or very cold (18°F [-10C] or less).

-Where the set will be exposed to direct sunlight.

-Where the humidity is high.

-Where there is strong vibration.

-Where it is dusty.

-Where there is steam and heat.

Storing the R/C set in the places listed above may cause distortion, corrosion and product failure.

If the R/C set will not be used for a long time, remove the nicd batteries from the transmitter and the model and store them in a dry place.

If the batteries are left in the transmitter and model, the battery electrolyte may leak out and damage the system, degrade the performance and shorten the life of the transmitter and model.

Nicd Battery Recycling (for USA only)

Used nicd batteries are an important resource. Stick tape over the terminals and take the used batteries to a nicd battery recycling center.

The RBRC Battery Recycling Seal on the nickel-cadmium (Ni-Cd) battery that should be used in our product, indicates Hobbico is voluntarily participating in an industry program to collect and recycle these batteries at the end of their useful life, when taken out of service in the United States or Canada. The RBRC program provides a convenient alternative to placing used Ni-Cd batteries into the trash or the municipal waste system, which is illegal in some areas. Please call 1-800-822-8837 for information on Ni-Cd battery recycling in your area. Hobbico's involvement in this program is part of our commitment to preserving our environment and conserving our natural resources.

Other Precautions

⚠CAUTION

Do not get fuel, oil, etc. on plastic parts.

The plastic may melt, discolor, become brittle and fail to function.

Always use Genuine Futaba transmitters, receivers, servos, ESCs, nicd batteries, and other optional parts.

Futaba is not responsible for damage, etc. caused by the use of parts other than Genuine Futaba parts.

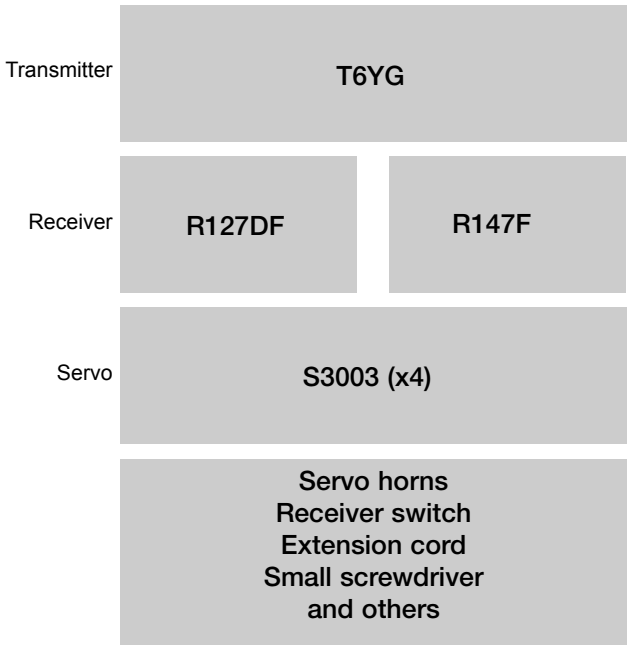
Use the parts described in the instruction manual and catalogs.

BEFORE USE

Set Contents

After opening the carton, first check if the following items are provided.

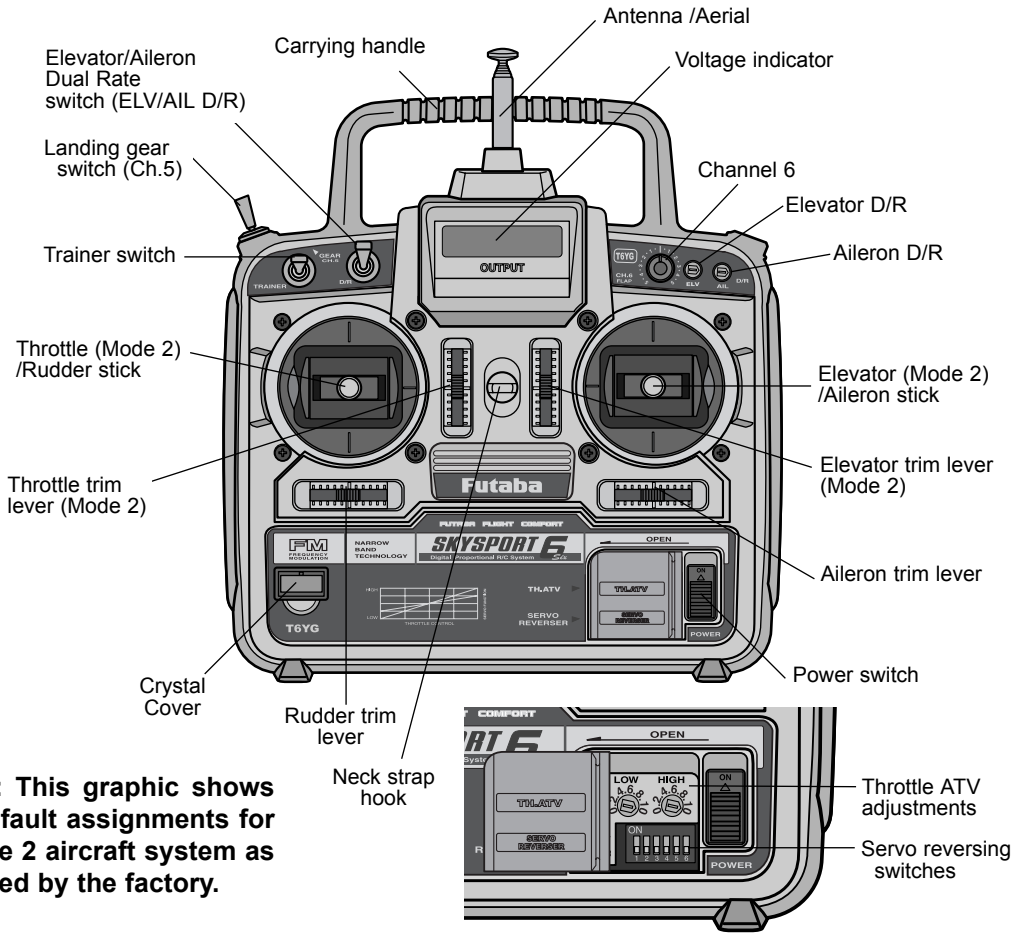
The set contents depend on the type of set, and these are the standard.



If the set contents are incomplete, or if you have any questions, please contact the dealer.

Name and Handling of Each Part

Transmitter T6YG (Front Panel)



NOTE: This graphic shows the default assignments for a Mode 2 aircraft system as supplied by the factory.

Power switch: Turns the transmitter "On" or "Off". In the upper position, the power is turned "On".

Voltage indicator: This is an expanded scale voltmeter. It is not calibrated in volts. When the needle deflects to the boundary between the silver and red zones, recharge or replace the battery. Do not operate the transmitter if the needle descends into the red area.

Antenna /Aerial: Never operate the transmitter without extending this antenna or you may create interference to other modelers. This antenna is not intended to be removable.

Aileron, Elevator, Throttle and Rudder stick: Control each function. See page 14 for the transmitter operation instructions.

Aileron, Elevator, Throttle and Rudder trim: Used to shift the neutral or idle position of the each servo. As the throttle stick is moved up towards the high throttle position, the throttle trim will have less effect.

Carrying handle: Provides an easy means of transporting the transmitter.

Neck strap hook: Only clip the neck strap to this hook when neck strap use is required.

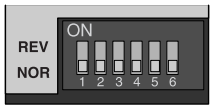
Servo reversing switches: Switches that reverse the direction of operation of the servos. The lower position is the normal side and the upper position is the reverse side.

Channel display

1 :Aileron (CH1) **3** :Throttle (CH3) **5** :Landing gear (CH5)
2 :Elevator (CH2) **4** :Rudder (CH4) **6** :Flap (CH6)

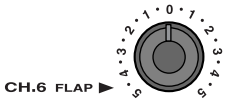
<Operating direction display>

REV :Reverse side
NOR :Normal side

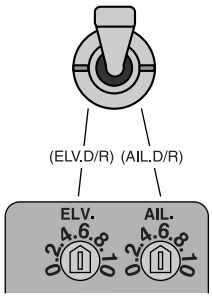


Landing gear switch: Controls the raising and lowering of retractable landing gear. Not all models will use this function.

Flap knob: Controls the flap servo(CH6).



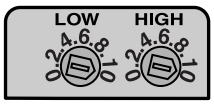
Dual Rate switch (AIL. D/R/ELV. D/R):
Dual Rate trimmers (AIL./ELV.):
Used to set to reduce the servo travel by flipping each Dual Rate switch. The travel reduction for the aileron and elevator may be set by each trimmer. See page 18 for the aileron/elevator dual rate function operation instructions.



Throttle ATV Trimer (Low/High)

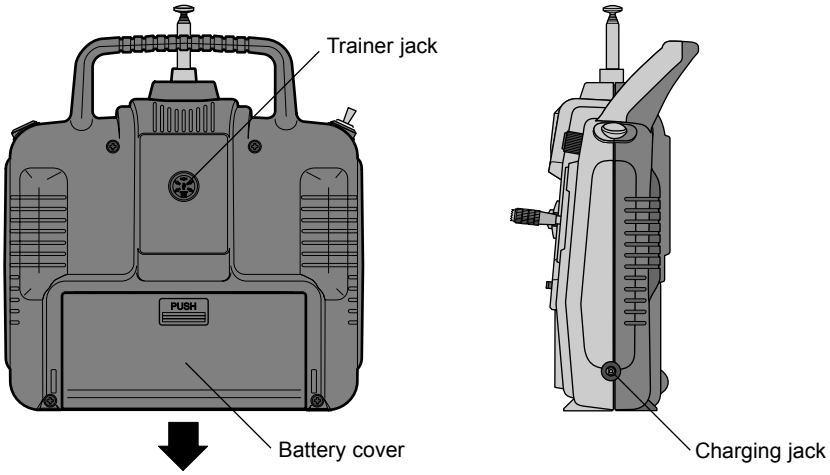
Used to adjust throttle servo travel limits.

Servo travel can be adjusted independently in each direction



Trainer switch: Controls the link between the instructor and student transmitters when using the trainer function. The student transmitter can only be operated when this switch is being activated.

Transmitter T6YG (Rear Panel/Side Panel)



Trainer jack: Connects the trainer cord when using the trainer function. The trainer cord is sold separately. See page 19 for the trainer function operation instructions.

Battery cover: Use when replacing the battery. Slide the cover downward while pressing the area marked "PUSH".

Charging jack: Charging jack used when charging the transmitter nicd battery.

⚠CAUTION

Do not charge Dry Batteries.

Charging dry batteries will cause overheating or breakage and electrolyte leakage and result in burns or damage by the chemical content.

Charging the Nicad Battery

⚠WARNING

Never plug the special slow charger into an AC outlet other than the voltage specified shown on the charger.

If the charger is plugged into an AC outlet other than the specified voltage, overheating, sparking, etc, may cause burns, fire, etc.

Use the special slow charger, or R/C quick charger, sold separately, to charge the R/C nicad batteries.

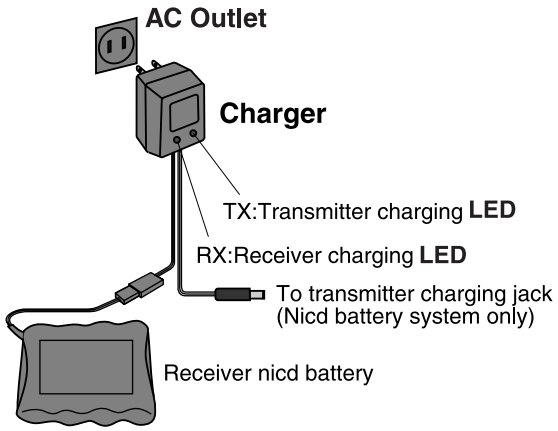
Overcharging will cause burns, fire, injury, or blindness due to overheating, breakage, electrolyte leakage, etc.

⚠CAUTION

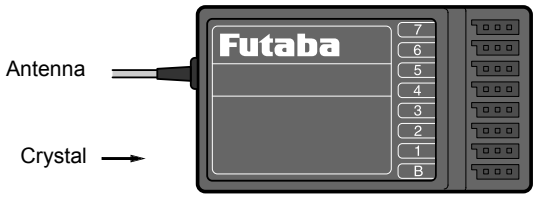
When not using the nicad battery charger, disconnect it from the AC outlet.

The transmitter and receiver nicad batteries can be charged simultaneously or independently.

1. **Connect the charger transmitter connector to the transmitter charging jack and the charger receiver connector to the receiver servo nicad battery.**
2. **Connect the charger to an AC outlet.**
3. **Check that the charging LED is lit.**
4. **At the end of charging, disconnect the charger from the AC outlet.**



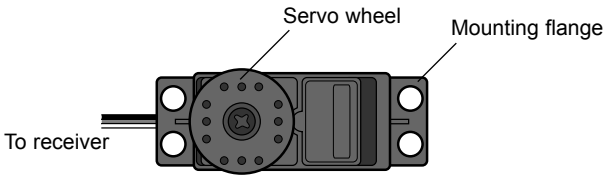
Receiver R127DF/R147F



"7": Not Used (CH7)
"6": Flap servo (CH6)
"5": Gear servo (CH5)
"4": Rudder servo (CH4)
"3": Throttle servo (CH3)
"2": Elevator servo (CH2)
"1": Aileron servo (CH1)
"B" Battery Connector

Crystal: The crystal is installed at the side of the receiver.

Servo S3003



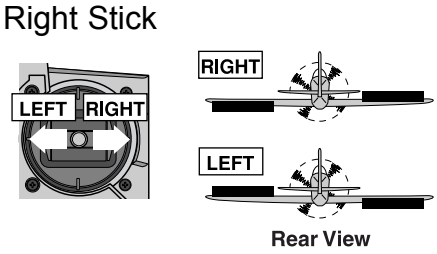
Accessories: The following items are supplied with the set:
-Spare servo horns: Use to match the application.
-Servo mounting parts: Rubber grommets, etc.

Transmitter Operation and Movement of Each Servo

Before making any adjustments, learn the operation of the transmitter and the movement of each servo. (In the following descriptions, the transmitter is assumed to be in the operating state.)

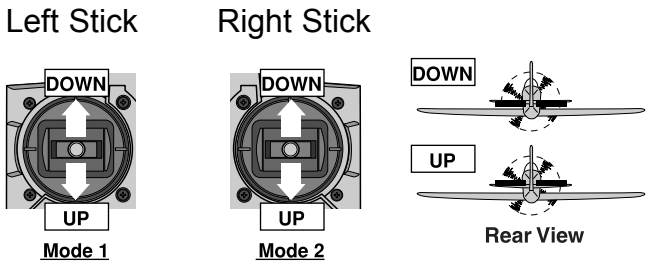
Aileron Operation

When the aileron stick is moved to the right, the right aileron is raised and the left aileron is lowered, relative to the direction of flight, and the plane turns to the right. When the aileron stick is moved to the left, the ailerons move in the opposite direction. To level the plane, the aileron stick must be moved in the opposite direction. When the aileron stick is moved and held, the plane will roll.



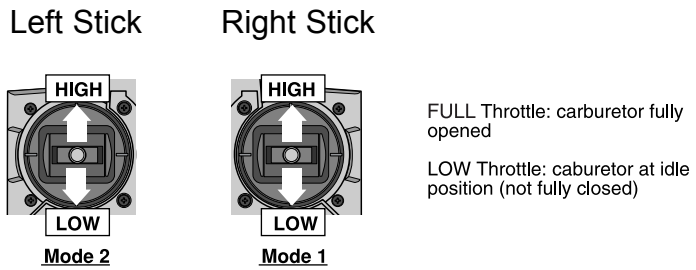
Elevator Operation

When the elevator stick is pulled back, the tail elevator is raised and the tail of the plane is forced down, the air flow applied to the wings is changed, the lifting force is increased, and the plane climbs (UP operation). When the elevator stick is pushed forward, the elevator is lowered, the tail of the plane is forced up, the air flow applied to the wings is changed, the lifting force is decreased, and the plane dives (DOWN operation).



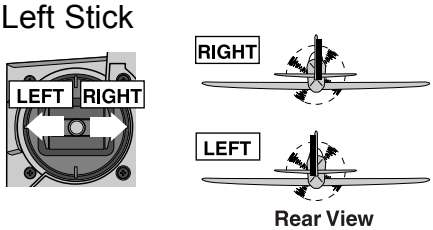
Throttle Operation

When the throttle stick is pulled back (low throttle), the engine throttle lever arm moves to the SLOW (low speed) side. When the throttle stick is pushed forward (full throttle), the throttle lever arm moves to the HIGH (high speed) side.



Rudder Operation

When the rudder stick is moved to the right, the rudder moves to the right and the nose moves to the right, relative to the direction of flight. When the rudder stick is moved to the left, the rudder moves to the left and the nose moves to the left.



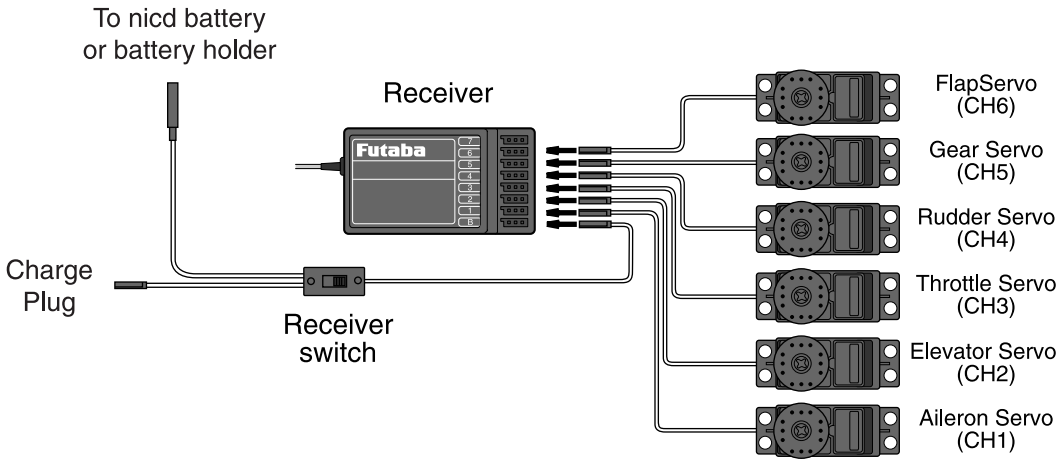
INSTALLATION AND ADJUSTMENT

This section describes the installation and adjustment of the receiver, servos, etc. to the plane.

Connections

Connection examples are shown below.

Connection Example



•Four servos are supplied as standard.

⚠WARNING

(Connector Connection)

Insert the receiver, servo, and battery connectors fully and firmly.

If vibration, etc. causes a connector to work loose during flight, the plane may crash.

(Receiver Vibration proofing / Waterproofing)

Vibration proof the receiver and battery by wrapping them in sponge rubber or some such material. If the receiver may get wet, waterproof them separately by placing them in plastic bags or balloons.

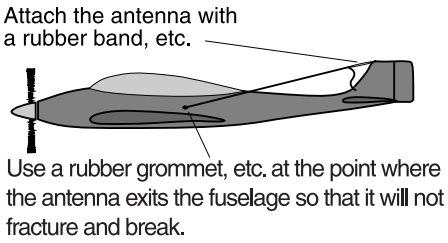
If the receiver is subjected to strong vibration and shock, or gets wet, it may operate erroneously and cause a crash.

(Receiver Antenna)

Do not cut or bundle the receiver antenna. Also, do not bundle the antenna together with the servo lead wires.

Cutting or bundling the receiver antenna will lower the receiver sensitivity and shorten the flight range and cause a crash.

Antenna installation: For aircraft, attach the antenna to the top of the tail.


Attach the antenna with a rubber band, etc.
Use a rubber grommet, etc. at the point where the antenna exits the fuselage so that it will not fracture and break.

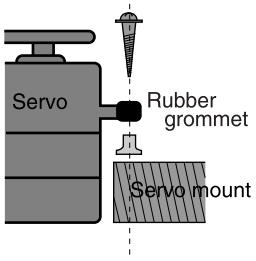
(Servo Throw)

Operate each servo over its full stroke and adjust the linkages so that the pushrod does not bind or is not too loose.

Unreasonable force applied to the servo horn will adversely affect the servo and drain the battery quickly.

(Servo Installation)

Install the servos to the servo mount, etc. using a rubber grommet. Also install the servos so that the servo case does not directly touch the servo mount or other parts of the fuselage.



(Servo Horn Screw)

Use the horn screw supplied with the servo.

If a long screw is used, the interior of the servo may be damaged.

Power Switch Installation

When installing a receiver power switch to the fuselage, cut a rectangular hole somewhat larger than the full stroke of the switch knob and install the switch so it moves smoothly from ON to OFF.

Always install the switch so it will not come into direct contact with engine oil, dust, etc. Generally, install the switch to the fuselage at the side opposite the muffler exhaust.

Adjustments

⚠CAUTION

The operating direction, neutral position, and steering angle of each servo are adjustable.

The basic linkage and adjustments, control layout, and servo, Rx and Nicad installation should conform to the fuselage design drawings and kit instruction manual. Be sure that the center of gravity is at the prescribed position.

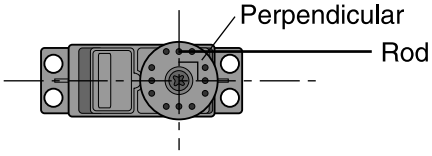
Adjustment Procedure

Before making any adjustments, set all the SERVO REVERSING switches on the front of the transmitter to the lower(NOR) position and set both Dual Rate trimmers(AIL./ELV.) to the maximum ("10") point. (Set the switches and the trimmers with a small screwdriver, etc.)

Turn on the transmitter and receiver power switches and make the following adjustments:

1. Check the direction of operation of each servo.

If a servo operates in the wrong direction, switch its SERVO REVERSING switch. (The direction of operation can be changed without changing the linkage.) Pay special attention to the direction of the aileron. (See page 14 for a transmitter operation instruction.)



2. Check the aileron, elevator, and rudder neutral adjustment and left-right (up-down) throw.

Check that when the Tx trim levers are in the center, the linkage connection point is perpendicular to the servo. In this position the control surfaces (aileron, elevator, rudder, etc.) must be neutral. If the neutral position of the control surface has changed, reset it by adjusting the length of the rod with the clevis.

When the throw is unsuitable (different from the deflection angle specified by the kit instruction manual), adjust it by either changing the servo horn, the position of the linkage on the servo horn or the linkage position on the control surface horn.

3. Check the engine throttle (speed adjustment) linkage.

Change the servo horn installation position and hole position so that the throttle is opened fully when the throttle stick is set to HIGH (forward) and is closed fully when the throttle stick and throttle trim are set for maximum slow (backward position and lower position, respectively).

4. After all the linkages have been connected, recheck the operating direction, throw, etc.

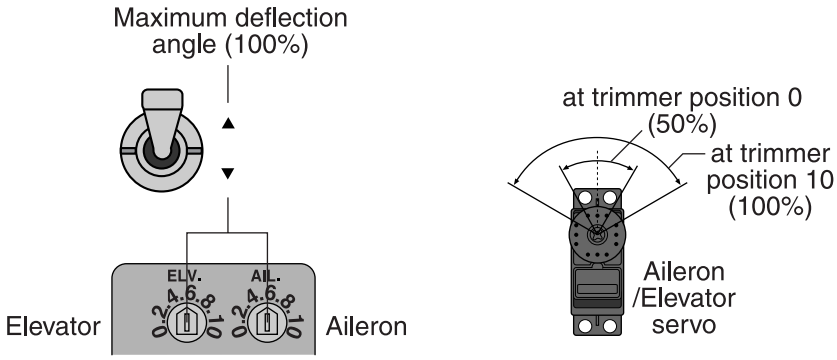
Before flight, adjust the aircraft in accordance with the kit and engine instruction manuals.

5. Fly the plane and trim each control for straight and level flight.

USING OTHER FUNCTIONS

Aileron/Elevator Dual Rate (D/R) Function

The maximum travel of the aileron and elevator servos can be altered by operating the dual rate switch. For instance, when the switch is in the lower position, the deflection angle is the normal deflection angle. The normal deflection angle, at the low switch position, can be adjusted by the dual rate trimmers (AIL/ELV). The rate can be adjusted from 50% (position 0) to 100% (position 10) of the maximum deflection angle. When the switch is set to the upper position, spins, snap rolls, and other aerobatics that require a maximum deflection angle can be performed.



1. Turn on the transmitter and receiver power.

2. Switch the dual rate switch (D/R) to the lower position.

3. Set the stick to the maximum travel in either direction.

4. Using the trimmer, adjust the servo horn to the desired angle.

Adjust each channel (AIL/ELV) by repeating steps 1 through 4.

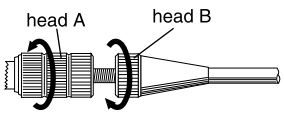
***When not using the dual rate function, set the AIL and ELV trimmers to 100% (fully clockwise).**

Non-slip Adjustable Lever Head

The length of the stick head can be adjusted.

1. Unlock two heads A and B by turning them in the arrow directions.

2. Adjust the stick to the most comfortable length and lock the heads by turning them in the opposite direction of the arrows.



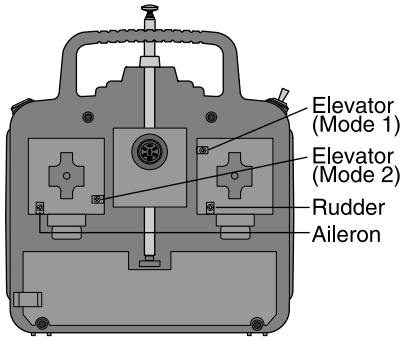
Stick Lever Spring Tension Adjustment

The operating feel of the aileron, elevator, and rudder sticks can be individually adjusted by adjusting the stick spring tension.

1. Remove the four transmitter rear case screws and carefully remove the rear case.

2. Adjust the spring tension by turning the screw of the channel you want to adjust (clockwise to stiffen counter-clockwise to soften).

3. Close the rear case and tighten the four screws.



Trainer Function

The trainer function is a very effective way for training students. To use it, the special trainer cord TC-FM (FUTM4410 USA only - sold separately) is necessary.

The special trainer cord can be connected to SKYSPORT4, SKYSPORT6, 7U series, 8U series, and PCM1024Z series transmitters.

⚠WARNING

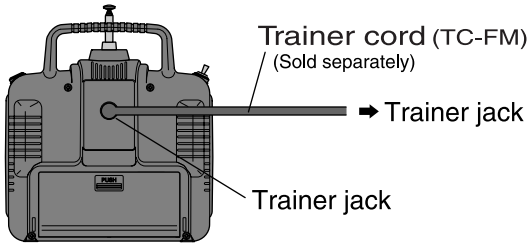
Never turn on the student transmitter power switch.
Turning on the power switch will cause interference and a crash.

Set the student and instructor transmitter functions and trims to the same settings.
For example, if the direction of operation is reversed, control will be lost and the plane will crash.

Both transmitters must have the modulation type that is FM type.
If the modulation type is different, control is impossible.

Connection

Connect the student and instructor transmitters with the trainer cord.



Operating Instructions

Instructor side: Turn "on" the power switch and extend the antenna to its full length. When the trainer switch is not activated, the instructor has control. When the trainer switch is activated, control is transferred to the student. Release the switch to retain control.

Student side: Never turn on the power switch.

REFERENCE

Ratings

Transmitter T6YG
(2 sticks, 6 channels, FM transmitter)

Transmitting frequency: 29, 35, 36, 40, 41, 50, 60, 72, or 75 MHz
Modulation method: FM(Frequency Modulation)
Power requirement: 12V (penlight battery x8) or 9.6V nicad battery
Current drain: 180mA

Servo S3003
(Standard servo)

Power requirement: 4.8V or 6V (common with receiver)
Current drain: 8mA (idle)
Output torque: 3.2kg-cm at 4.8V
Operating speed: 0.23sec/60 degrees at 4.8V
Size: 40.4x19.8x36mm
Weight: 37.2g

Receiver R127DF
(7 channels, FM receiver)

Receiving frequency: 50, 72, or 75 MHz
Intermediate frequency: 1st IF 10.7MHz 2nd IF 455kHz
Power requirement: 6V (penlight battery x4), 4.8V or 6v NiCd battery (common with servo)
Current drain: 10mA
Size: 64.3 x 35.8 x 21mm
Weight: 40.5g

Receiver R147F
(7 channels, FM receiver)

Receiving frequency: 29, 35, 36, 40, 41, 72 MHz
Intermediate frequency: 455kHz
Power requirement: 6V (penlight battery x4), 4.8V or 6v NiCd battery (common with servo)
Current drain: 14mA
Size: 24.2 x 64 x 17.6mm
Weight: 26g

Note: Specifications and ratings are subject to change without prior notice and may differ from country to country.

Troubleshooting

If your R/C set does not operate, its range is short, it intermittently stops operating, or it operates erroneously, take the action shown in the table below. If this does not correct the trouble, please contact a Futaba dealer.

Check point	Check item	Action
Transmitter/receiver battery	Dead battery.	Replace the battery. Charge the NiCd battery.
	Incorrect loading.	Reload the batteries in the correct polarity.
	Faulty contact connection.	If the contact spring is deformed, correct it.
	Dirty contacts.	Wipe with a dry cloth.
Transmitter antenna	Loose.	Screw in.
	Not extended to full length.	Extend fully.
Crystal	Disconnected.	Push in.
	Wrong band.	Match transmitter/receiver band.
	Different from specification.	Replace with specified crystal.
Connector connection	Incorrect wiring.	Reinsert.
	Disconnection.	Push in.
Receiver antenna	Close to other wiring.	Separate from other wiring.
	Cut?	Request repair.
	Bundled?	Install in accordance with instruction manual.
Servo linkage	Binding or looseness	Adjust at the fuselage.
Motor (electric motor plane)	Noise countermeasures.	Install a noise absorbing capacitor.

Glossary

The following defines the symbols and terms used in this instruction manual.

Aileron (AIL)

Control surface on the left and right sides of the main wing of an aircraft. It usually controls banking of the aircraft.

Channel

Represents the number of control functions. It can also represent the number of servos that are operated.

Down

Means "down" elevator. It is the direction in which the trailing edge of the elevator moves.

Dual Rate (D/R)

Reduces the servo travel by flipping a switch.

Elevator (ELV)

Control surface that moves up and down on the horizontal stabilizer of an aircraft. It usually controls up and down. (Altitude)

Linkage

Mechanism that connects the servos and the fuselage or wing control surfaces.

Modulation Method

Two modulation methods are used with radio control: AM (Amplitude Modulation) and FM (Frequency Modulation). Radio sets for aircraft mainly use FM. Another method that encodes and transmits the modulated signals is called "PCM".

Neutral

Means the neutral position. It is the state in which a transmitter stick returns to the center when not operated.

Normal (NOR)

For the servo reversing function, it is the normal side. The opposite side is the reverse side.

Rudder (RUD)

Tail control surface that controls the direction of the aircraft.

Reverse (REV)

With the servo reversing function, this refers to the reverse side. The opposite side of reverse is the normal side.

Rod

A wire that connects the servos and the control surfaces.

Servo horn

A part that is installed to the shaft of a servo which changes the rotating motion of the servo to linear motion and transmits the linear motion to a rod. Servo horns come in various shapes.

Servo mount

Base for installing a servo in the aircraft.

Stick

Control for operating the transmitter.

Throttle (TH)

Part that controls the air mixture at the engine intake. When opened (throttle high position), a large air mixture is sucked in and the engine speed increases. When closed (throttle low position), the engine speed decreases.

Trim

A device that fine adjusts the neutral point of each servo for safe flying. It is a mechanism that corrects unbalanced tendencies of the aircraft.

Up

Means "up" elevator. It is the direction in which the trailing edge of the elevator moves.

Repair Service (for USA)

Before requesting repair, read this instruction manual again and recheck your system. Should the problem continue, request repair service as follows:

Describe the problem in as much detail as possible and send it with a detailed packing list together with the parts that require service.

- Symptom (Including when the problem occurred)
- System(Transmitter, Receiver, Servos and model numbers)
- Model (Model name)
- Model Numbers and Quantity
- Your Name, Address, and Telephone Number.

Futaba®
Digital Proportional R/C System

1610 Interstate Dr. Champaign, IL 61822 (217) 398-0007

FUTABA CORPORATION
Makuhari Techno Garden Bldg., B6F 1-3 Nakase, Mihama-ku, Chiba 261-8555, Japan
Phone: (043) 296-5118 Facsimile: (043) 296-5124

BLUE SEA SYSTEMS
Marine Electrical Products

DC Power Distribution Panel

PN 8023 / PN 3023 / PN 8025 / PN 3025 / PN 8264 / PN 3264
PN 8375 / PN 3375 / PN 8376 / PN 3376 / PN 8377 / PN 3377

Panel Specifications

Material:	0.125” 5052-H32 Aluminum Alloy		
Primary Finish:	Chemical Treatment per Mil Spec C-5541C		
Final Panel Finish:	Graphite color 2 part textured Polyurethane		
Circuit Breakers:	15 amp AC/DC Magnetic 65V DC/277V AC Maximum		
Amperage Rating:	All components are sized for 100 Amps of continuous current		
Voltage Rating:	Panels are rated for 12 or 24 volt DC distribution. Configure your panel with the supplied voltage identification labels.		
	PN	**Inches**	**Millimeters**
Overall Dimensions:	8023/3023	5-1/4 x 7-1/2	133.4 x 190.5
	8025/3025	5-1/4 x 3-3/4	133.4 x 95.3
	8264/3264	14-3/4 x 7-1/2	374.7 x 190.5
	8375/3375	14-3/4 x 4-1/2	374.7 x 114.3
	8376/3376	5-1/4 x 11-1/4	133.4 x 285.8
	8377/3377	10-1/2 x 7-1/2	266.7 x 190.5
Mounting Centers:	8023/3023	4-7/16 x 6-11/16	112.7 x 169.9
	8025/3025	4-7/16 x 2-15/16	112.7 x 74.6
	8264/3264	13-29/32 x 6-11/16	353.2 x 169.9
	8375/3375	13-29/32 x 3-11/16	353.2 x 93.7
	8376/3376	4-7/16 x 10-7/16	112.7 x 256.1
	8377/3377	9-11/16 x 6-11/16	246.1 x 169.9

Applicable Standards

- American Boat and Yacht Council (ABYC) Standards and Recommended Practices for Small Craft sections: E-1, E-3, E-9.
- United States Coast Guard 33 CFR Sub Part 1, Electrical Systems.

Document 9467 Rev.I

⚠ WARNING ⚠

- ☑ It is not possible within the scope of these instructions to fully acquaint the installer with all the knowledge of electrical systems that may be necessary to correctly install this product. If the installer is not knowledgeable in electrical systems we recommend that an electrical professional be retained to make the installation.
- ☑ If either the panel front or back is to be exposed to water it must be protected with a waterproof shield.
- ☑ The panels must not be installed in explosive environments such as gas engine rooms or battery compartments as the circuit breakers are not ignition proof.
- ☑ The main positive connection must be disconnected at the battery post to avoid the possibility of a short circuit during the installation of this distribution panel.

Guarantee

Any Blue Sea Systems product with which a customer is not satisfied may be returned for a refund or replacement at any time.

Useful Reference Books

Calder, Nigel, 1996: *Boatowner’s Mechanical and Electrical Manual*, 2nd edition, Blue Ridge Summit, PA: TAB Books, Inc.
Wing, Charlie, 1993: *Boatowner’s Illustrated Handbook of Wiring*, Blue Ridge Summit, PA: TAB Books, Inc.

Blue Sea Systems Inc.
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Bellingham, WA 98226 USA
Phone (360) 738-8230
Fax (360) 734-4195
E-mail conduct@bluesea.com
www.bluesea.com

Installation

1. Disconnect all AC and DC power

Before starting, disconnect the main positive cable from all batteries to eliminate the possibility of a short circuit while installing the distribution panel. Also disconnect the AC shore power cord from the boat to eliminate the possibility of electrocution from AC wiring in the proximity of the DC distribution panel.

2. Apply Voltage Label

All panel components are sized for 12 or 24 Volt systems. Use the labels provided to permanently identify the system voltage and its type (DC) as required by ABYC. Apply the appropriate voltage label to the recessed area on the front of the panel.

3. Select mounting location and cut opening

Select a mounting location which is protected from water on the panel front and back and is not in an area where flammable vapors from propane, gasoline or lead acid batteries accumulate. The circuit breakers used in marine electrical panels are not ignition protected and may ignite such vapors.

Using the panel template provided, make a cut out in the mounting surface where the distribution panel is to be mounted. Do not yet fasten the panel to the mounting surface.

4. Install positive feed wire and negative return

Determine the positive feed (red) and negative return (black or yellow) wire size by calculating the total amperage of the circuits that will be routed through the panel. Blue Sea Systems’ electrical panels are rated at 100 amp total capacity. The positive feed wire must be sized for 3% voltage drop at the 100 amp panel rating or the maximum amperage that will be routed through the panel in any particular installation, whichever is less. It is recommended that the positive feed wire be sized for the full panel capacity, which, in most cases, will require at least 2 AWG wire, assuming a 10 foot wire run between the panel and the batteries in 12 volt systems. Refer to the Wire Sizing Chart for other situations. Remember that the length of the circuit is the total of the positive wire from the power source and the negative wire back to the DC Negative Bus. Be certain that there is a fuse or circuit breaker of the correct size protecting the positive feed wire. In the case of the 24 position panel, jumpers from positive bus to positive bus and from negative bus to negative bus should be the same size as the positve feed and the negative return wires.

5. Install branch circuit wires

Determine the proper wire size for each branch circuit using the guidelines in step 4. Verify that the standard 15 amp circuit breakers installed in the panel are large enough for each branch circuit. Remove and replace with a higher amperage any that are undersized.

Connect the positive (red) branch circuit wires to the load terminals of each circuit breaker.

Connect each negative (black or yellow) branch circuit wire to the DC Negative Bus. DO NOT CONFUSE THE DC NEGATIVE BUS WITH THE DC GROUNDING BUS.

6. Installation of Backlight System

Connect the yellow negative wire to the panel negative bus.

To activate the label lights by the boat’s battery switch, connect the red positive wire to the DC panel positive bus.

To activate the label lights by an independent switch or breaker, connect the red positive wire to the load side of the switch or breaker.

7. Optional - install grounding system wire

The grounding wire (bare, green or green with yellow stripe and normally non-current carrying) should not be confused with the negative ground wire (black or yellow and normally current carrying).

Installation (continued)

In *Boatowner's Illustrated Handbook of Wiring*, Charlie Wing identifies three purposes of DC Grounding:

1. Holding conductive housings of low voltage (under 50 volts) DC devices at ground potential by providing a low resistance return path for currents accidentally coming into contact with the device cases.
2. Providing a low resistance return path for electrical current, preventing stray currents that may cause corrosion.
3. Grounding metal electrical cases to prevent emission from inside or absorption from outside of radio frequency noise (RFI).

ABYC requires that grounding wires be sized no smaller than one wire size under that required for current carrying conductors supplying the device to which the grounding wire is connected.

A full treatment of this subject is not possible within the scope of these instructions and there is controversy surrounding the general subject of DC bonding, of which DC grounding is a component. It is suggested that installers not familiar with this subject consult one of the reference books listed elsewhere in these instructions.

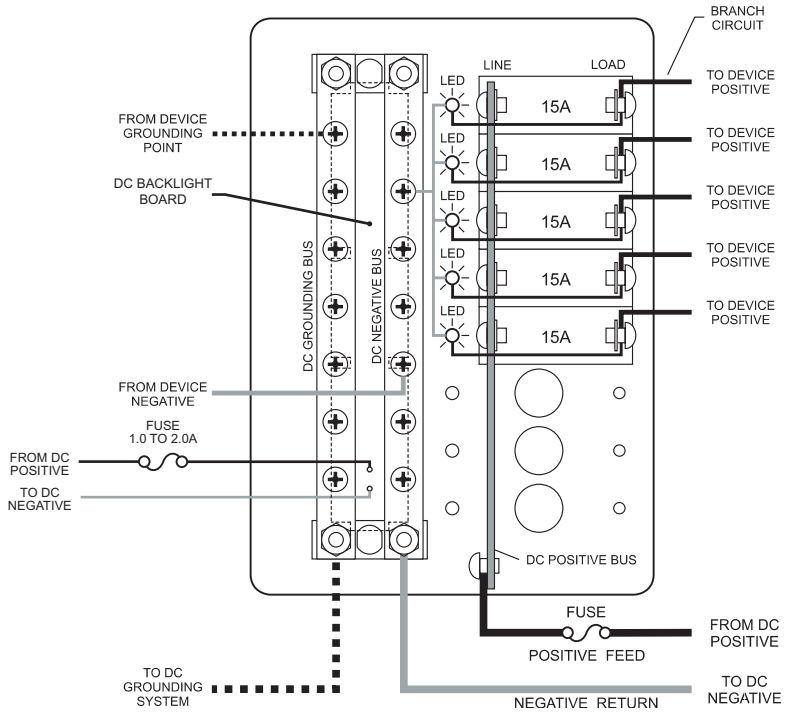
8. Apply branch circuit labels and mount panel

Apply a label for each of the branch circuits from the 30 basic labels provided. If the appropriate label is not included, the Extended Label Set of 120 labels may be ordered from your marine supplier (PN 8039). Individual labels are also available from Blue Sea Systems for specific applications. Refer to the label order form for a complete listing of individual labels.

Fasten the panel to the mounting surface using the panel mounting screws supplied with the panel.

9. Testing

Reconnect the main positive cable to the battery terminals and turn the main switch on to supply power to the panel. Turn on all branch circuits and test the voltage at the panel. Compare this voltage to the battery terminal voltage to determine that the voltage drop is within 3%. With all branch circuits still on, test the voltage at one device on each circuit to determine that there is a 3% or 10% drop as is appropriate.



Wiring Diagram
DC Power Distribution Panel
(PN 8023 /PN 3023 shown for reference)

Optional Branch LED's

This Panel is supplied with LED's pre-installed in all optional branch positions. For future expansion of the panels remove the positive leg of the LED from the negative busbar and connect it to the load side of the corresponding branch circuit breaker.

Note

This Blue Sea Systems electrical distribution panel is furnished with 15 amp AC/DC circuit breakers. This rating was selected to minimize the need for removing the panel's circuit breakers and reinstalling different size circuit breakers. As shown in the Wire Sizing Chart included with these instructions, even 16 AWG wire, which is the minimum wire size recommended by ABYC, has an allowable amperage greater then 20 amps. Additionally, it would be rare to have more than 15 amps of current flowing in any one circuit. Therefore, 15 amp circuit breakers will satisfy the vast majority of marine circuit protection situations.

The Purpose of a Panel

There are five purposes of a marine electrical panel:

- Power distribution
- Circuit (wire) protection
- Circuit ON/OFF switching
- Metering of voltage and amperage (In panels with meters)
- Condition Indication (circuit energized)

Related Products from Blue Sea Systems

PanelBack Insulating Covers
High Amperage Fuses and Circuit Breakers for positive feed wires
High Amperage Battery Switches
Terminal Blocks and Common Bus Connectors

Wire Sizing Chart

1. Calculate the maximum sustained amperage of the circuit. Measure the length of the circuit from the power source to the load and back.
2. Does the circuit run in an **engine space** or **non engine space**.
3. Calculate **Famps** (Feet x amps). Multiply circuit length by max. current.
4. Base the wire on either the 3% or 10% **voltage drop**. In general, items which affect the safe operation of the boat and its passengers (running lights, bilge blowers, electronics) use 3%; all other loads use 10%.
5. Starting in the column which has the right **voltage** and **voltage drop**, run down the list until arriving at a value which is greater than the calculated **Famps**. Move left to the **Ampacity** column to verify that the total amperage of the circuit does not exceed the maximum allowable amperage of the wire size for that row. If it does, move down until the wire ampacity exceeds the circuit amperage. Finally, move left to the **wire size** column to select the wire size.

Example

a. A 12 volt system at 10% drop with a 40' circuit x 45 amps = 1800 Famps. A wire size of 8 is required.

Wire Size	Wire Ampacity non-engine	Wire Ampacity engine	Voltage → Volt Drop →	12 3% Famps	12 10% Famps	24 3% Famps	24 10% Famps	32 3% Famps	32 10% Famps
16	25.0	21.3		86	288	173	576	230	768
14	35.0	29.8		138	459	275	918	367	1223
12	45.0	38.3		219	729	437	1458	583	1944
10	60.0	51.0		348	1159	695	2317	927	3090
8	80.0	68.0		553	1843	1106	3686	1474	4915
6	120.0	102.0		879	2929	1757	5858	2343	7811
4	160.0	136.0		1398	4659	2796	9319	3727	12425
2	210.0	178.5		2222	7408	4445	14815	5926	19754
1	245.0	208.3		2803	9342	5605	18684	7474	24912
0	285.0	242.3		3536	11788	7073	23576	9430	31434
00	330.0	280.5		4457	14858	8915	29715	11886	39620
000	385.0	327.3		5619	18731	11239	37462	14985	49950
0000	445.0	378.3		7086	23620	14172	47241	18896	62988

Note: For wire with 105°C insulation rating and AWG wire sizes.

Chart courtesy of the West Advisor

APPENDIX C – DETAILED BILL OF MATERIALS

Hull - Bill of Materials

Component	Part Number	Material Description	Thickness (inches)	Width (inches)	Length (inches)	Channel Depth (inches)	Qty	Total Length(ft)	Total Area (ft^2)	Total Weight (lbs)	Total Cost
Frame	1	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	4.5	-	2	0.75		0.32	$0.90
Members	2	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	21	-	2	3.50		1.48	$4.20
	3	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	22.375	-	7	13.05		5.51	$15.66
	4	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	26.5	-	2	4.42		1.86	$5.30
	5	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	38.6875	-	2	6.45		2.72	$7.74
	6	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	39	-	1	3.25		1.37	$3.90
	7	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	42	-	3	10.50		4.43	$12.60
	8	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	60	-	2	10.00		4.22	$12.00
	9	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	39.3125	-	2	6.55		2.76	$7.86
	10	6061-T6 Equal Leg Aluminum Angle	0.125	1.5	42.4375	-	2	7.07		2.98	$8.49
	11	6061-T6 Channels	0.15625	0.75	40	1.5	2	6.67		3.40	$20.53
	12	6061-T6 Channels	0.15625	0.75	42	1.5	2	7.00		3.57	$21.56
	13	5052-H32 Aluminum Plate	0.250	0.5	39	-	1	3.25	0.14	0.4768	$1.48
	14	5052-H32 Aluminum Sheet - Mill Finish	0.081	5	26	-	5	10.83	4.51	5.1503	$12.00
Hull Plating	15	5052-H32 Aluminum Sheet - Mill Finish	0.081	41	39	-	1	3.25	11.10	12.67	$29.52
	16	5052-H32 Aluminum Sheet - Mill Finish	0.081	41	25.25	-	1	2.10	7.19	8.20	$19.11
	17	5052-H32 Aluminum Sheet - Mill Finish	0.081	41.938	38.8125	-	1	3.23	11.30	12.90	$30.05
	18	5052-H32 Aluminum Sheet - Mill Finish	0.081	41.5	20.25	-	1	1.69	5.84	6.66	$15.52
	19	5052-H32 Aluminum Sheet - Mill Finish	0.081	42	24	-	1	2.00	7.00	7.99	$18.61
	20	5052-H32 Aluminum Sheet - Mill Finish	0.081	24	60	-	2	10.00	20.00	22.82	$53.17
	21	5052-H32 Aluminum Sheet - Mill Finish	0.081	42	84		1	7.00	24.50	27.95	$65.13

Hull - Bill of Materials

Component	Part Number	Material Description	Thickness (inches)	Width (inches)	Length (inches)	Channel Depth (inches)	Qty	Total Length(ft)	Total Area (ft^2)	Total Weight (lbs)	Total Cost
Misc.	22	6061-T6 10" Sch. 40 Pipe			12		1	1.00		14.00	$50.00
	23	Cover: 5052-H32 Aluminum Plate	0.250	13	13		1	1.08	1.17	4.13	$12.81
	24	Flange: 5052-H32 Aluminum Plate	0.250	13	13		4	4.33	4.69	16.53	$51.24
	25	Plexiglass					1				$20.00
	26	Gasket					1				$15.00
	27	Latch					8				$80.00
	28	Taco Weather Seal					1				$25.00
	29	Sea Sense: 12 volt Bilge P/P, Float, and Fittings					1				$60.00
	30	Carrying Handle					4				$10.00
	31	Marine Epoxy Paint					2 gal				$70.00
	32	Metal Primer Paint					1 gal				$35.00
	33	Shop supplies, fasteners, etc.									$75.00

Hydrophone Array - Bill of Materials

Component	Part Number	Material Description	Thickness (inches)	Width (inches)	Length (inches)	Density (lbs/ft)or (lbs/ft^2)	Diameter (inches)	Qty	Total Weight (lbs)	Total Cost
Array Frame	1	6061-T6 Aluminum Angle	0.125	1	50	0.282	-	4	4.70	$12.93
	2	6061-T6 Aluminum Angle	0.125	1	44	0.282	-	1	1.03	$2.84
	3	6061-T6 Aluminum Angle	0.125	1	32	0.282	-	6	4.51	$12.41
	4	6061-T6 Aluminum Angle	0.125	1	8	0.282	-	12	2.26	$6.20
	5	1/4" x 3/4" Stainless Steel Nuts and Bolts	-	-	-	-	-	40	-	$20.00
Hydrophone Bottom Plate*	6	5052-H32 Aluminum Sheet - Mill Finish	0.081	-	-	1.141	8	1	0.398	

*Cost included in Bill of Materials for the hull

Propulsion System - Bill of Materials

Component	Part Number	Material Description	Thickness (inches)	Width (inches)	Length (inches)	Diameter (inches)	Shaft Length (inches)	Density (lbs/ft) or (lbs/ft²)	Qty	Total Weight (lbs)	Total Cost
Motor	1	50 PD Trolling Motor	-	-	-	-	54	-	2	-	$1,550.00
Transom Mount	2	5052-H32 Aluminum Plate	0.25	3.00	26.00	-	-	3.521	4	7.63	$23.65
	3	5052-H32 Aluminum Plate	0.25	3.00	14.00	-	-	3.521	4	4.11	$12.73
	4	5052-H32 Aluminum Plate	0.25	3.00	3.00	-	-	3.521	8	1.76	$5.46
	5	5052-H32 Aluminum Plate	0.25	6.00	12.00	-	-	3.521	2	3.52	$10.92
	6	Miscallaneous Mounting Hardware	-	-	-	-	-	-	-	-	$10.00

Electrical System - Bill of Materials

Component	Part Number	Material Description	Thickness (inches)	Width (inches)	Length (inches)	Density (lbs/ft) or (lbs/ft²)	Qty	Total Weight (lbs)	Total Cost
Electrical Equipment Frame	1	5052-H32 Aluminum Sheet - Mill Finish	0.081	1	12.5	1.141	4	0.3962	$1.29
	2	5052-H32 Aluminum Sheet - Mill Finish	0.081	1	19.5	1.141	6	0.9271	$3.01
	3	5052-H32 Aluminum Sheet - Mill Finish	0.081	1	21	1.141	6	0.9984	$3.24
	4	5052-H32 Aluminum Sheet - Mill Finish	0.081	9.5	21	1.141	1	1.5808	$5.14
	5	5052-H32 Aluminum Sheet - Mill Finish	0.081	19.5	21	1.141	1	3.2447	$10.55
Box for Electrical Frame	5	5052-H32 Aluminum Sheet - Mill Finish	0.081	1	14	1.141	4	0.4437	$1.44
	6	5052-H32 Aluminum Sheet - Mill Finish	0.081	1	20.5	1.141	4	0.6497	$2.11
	7	5052-H32 Aluminum Sheet - Mill Finish	0.081	1	22.5	1.141	4	0.7131	$2.32
	8	5052-H32 Aluminum Sheet - Mill Finish	0.081	20.5	22.5	1.141	2	7.3095	$23.76
	9	5052-H32 Aluminum Sheet - Mill Finish	0.081	14	20.5	1.141	2	4.5482	$14.78
	10	5052-H32 Aluminum Sheet - Mill Finish	0.081	14	22.5	1.141	2	4.9919	$16.22
	11	Hinge for cover							
	12	Gasket							
	13	Rubber Stops							
Frame for Camera and Gyro	14	5052-H32 Aluminum Sheet - Mill Finish	0.125	4	5	1.762	2	0.4894	$1.59
	15	6061-T6 Aluminum Square Bar	-	0.5	4	0.294	4	0.392	$1.08
Batteries	10-3199-6	Motomaster Nautilus Deep Cycle Battery 103 Amp Hr Capacity	6.9	8.9 (height)	13.1		4	200	$479.96
Battery Mounts	16	5052-H32 Aluminum Sheet - Mill Finish	0.081	1	13.35	1.141	8	0.8462	$2.75
	17	5052-H32 Aluminum Sheet - Mill Finish	0.081	1	6.9	1.141	8	0.4374	$1.42
	18	6061-T6 Aluminum Clip					8		$1.00

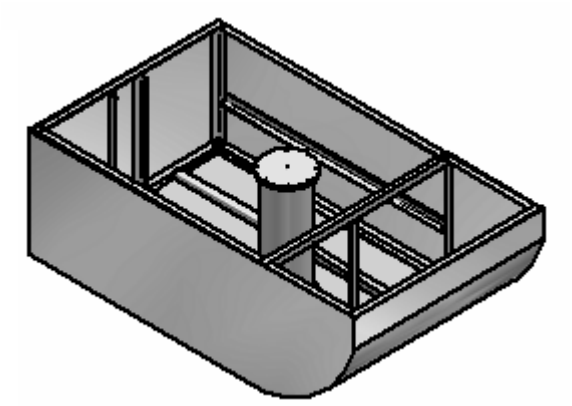
Control System - Bill of Materials

Component	Part Number	Material Description	Thickness (inches)	Width (inches)	Length (inches)	Diameter (inches)	Density (lbs/ft) or (lbs/ft²)	Qty	Total Weight (lbs)	Total Cost
Remote Control Unit	1	Futaba 8 Channel RC Package						1		$500.00
	2	Miscellaneous Integration Components								$100.00

APPENDIX D – HULL AND PROPULSION CALCULATIONS

Sample Calculation Draft

Monotype Displacement Hull



Hull Parameters based on ¼ model

Longitudinal 72” ~ model 18”
Beam 42” ~ model 10 ½”
Vertical Depth ~ model 6”
Bow Radius 25” ~ model 6 ¼”

Assumptions
Estimated 700lbs Payload
Usage for Fresh Water
Calculations Treat Hull as a Solid Block

Archimedes Principle

$$\Delta = \gamma * \nabla \qquad \gamma = \frac{1}{36\ \text{ft}^3 / \text{tonn}}$$

$$700\text{lbs} * \frac{1\ \text{tonn}}{2000\ \text{lbs}} = 0.35\text{tonnes}$$

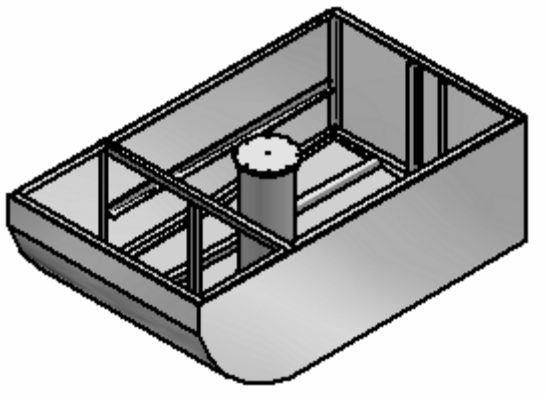
$$\nabla = \frac{\Delta}{\gamma} = \frac{0.35\ \text{tonnes}}{\frac{1}{36\ \text{ft}^3 / \text{tonn}}} = 12.6\text{ft}^3$$

∇ = Volume to be displaced by hull

Δ = 700 lbs at Full Ship Scale ~ 10.9 lbs at Model Scale

Estimated Draft T is:
12.6 ft3 = 6 ft x 3.5 ft x T
T = 0.6 ft or 7.2 inches

Sample Calculation Effective Horse Power



EHP Calculation for Tow Tank Testing
Performed November 17th, 2004

Trial # 1
For Displacement Hull
Full Ship Dimensions
- Longitudinal 60”
- Beam 42”
- Depth 16”
Correction Factor 0.004

No Hydrophone Array Attached

Measured Data:

Trial #	Distance (ft)	Time (s)	Velocity (ft/s)	Sm (ft^2)	$R_{T,M}$ (lb)
1	16.416	5.44	3.0178	1.31	0.75

Linear Scale Ratio

$$\lambda = \frac{60"}{15"} = 4$$

Model Wetted Surface varies as Inverse of Scale Ratio Squared

$S_m = 1.31$ $\quad \Delta_m = 10.9375\text{lbs}$ $\quad S_S = 4^2 * 1.31 = 20.96$

Model

$$C_{T,m} = \frac{R_{T,M}}{\frac{1}{2} * \rho * Vm^2 * Sm} = \frac{0.75}{\frac{1}{2} * 1.9365 * 3.0178^2 * 1.31} = 0.064926$$

$$R_{n,m} = \frac{V_m * 1.25}{1.066 \times 10^{-5}} = \frac{3.0178 * 1.25}{1.066 \times 10^{-5}} = 353866.043 \text{ Model Reynolds Number}$$

$$C_{F,m} = \frac{0.075}{(\log_{10}(R_{n,m} - 2)^2} = \frac{0.075}{(\log_{10}(353866.043 - 2)^2} = 0.0059551$$

$$C_{R,S} = C_{T,M} - C_{F,M} = 0.064926 - 0.0059551 = 0.05897265$$

Full Scale Ship

$V_S = V_m \sqrt{\lambda}$ $\quad V_S = 6.04\ (\text{ft/s})$

$$R_{n,S} = \frac{V_S * 5}{1.066 \times 10^{-5}} = \frac{6.04 * 5}{1.066 \times 10^{-5}} = 2830928.34 \text{ Ship Reynolds Number}$$

$$C_{F,S} = \frac{0.075}{(\log_{10}(R_{n,S} - 2)^2} = \frac{0.075}{(\log_{10}(2830928.34 - 2)^2} = 0.00378412$$

$$C_{T,S} = C_{R,S} - C_{F,S} + C_A = 0.05897265 - 0.00378412 + 0.004 = 0.06315677$$

Full Scale Ship

$V_S = 3.58$ $\quad\quad$ $V_S = 6.04$ (ft/s)

$$R_{T,S} = C_{T,S} * \tfrac{1}{2} * \rho * V_s^2 * S_S = 0.06315677 * \tfrac{1}{2} * 1.9365 * 6.04^2 * 20.96$$

$R_{T,S} = 46.69$ (lb)

$$EHP = \frac{R_{T,S} * V_S}{550} = 0.51$$

Tow Tank Testing: Wednesday, November 17, 2004

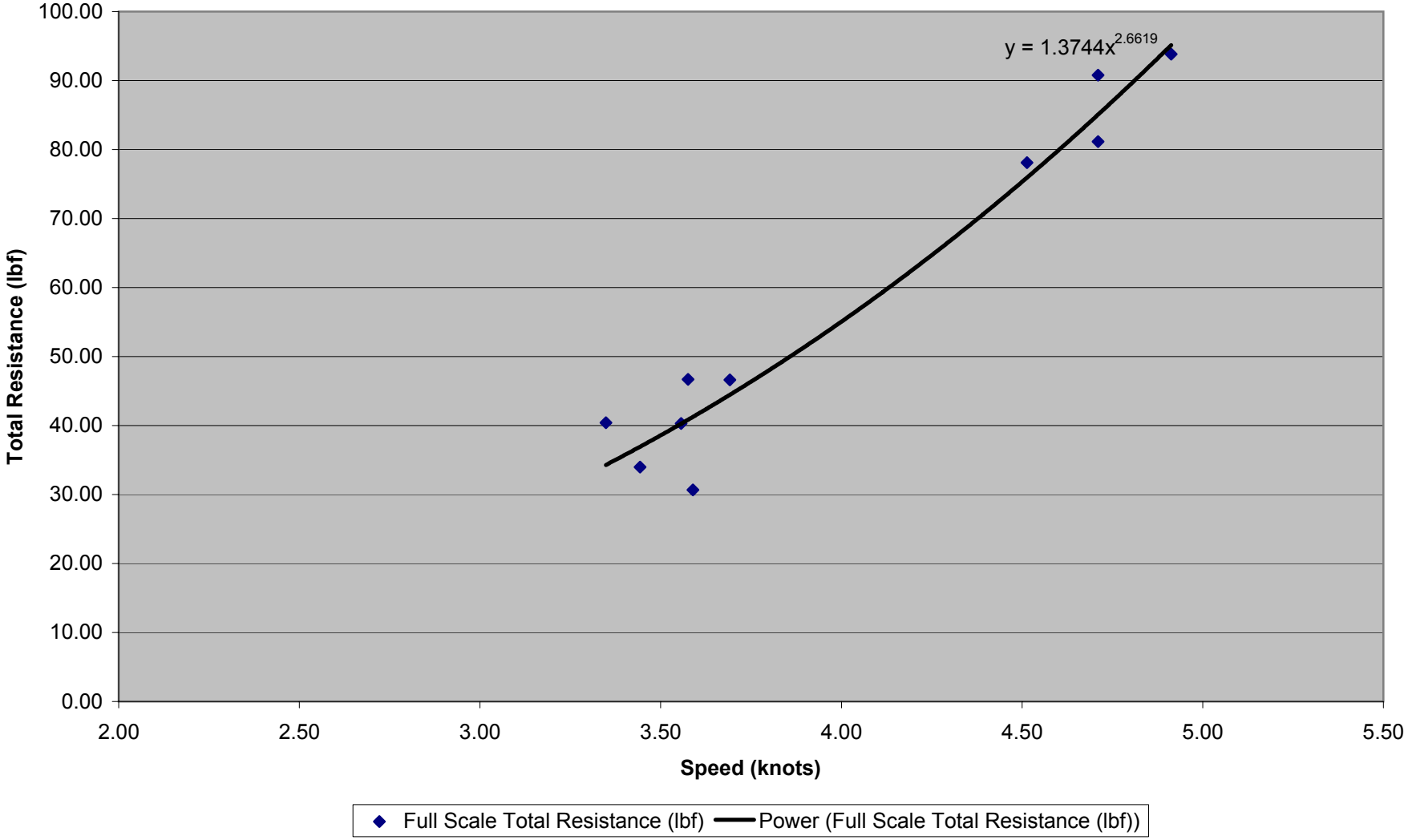
Trial	Distance (m)	Time (s)	Velocity (m/s)	VM (ft/s)	RT,M (lb)
1	5.0038	5.44	0.92	3.0178	0.75
2	5.0038	5.42	0.92	3.0289	0.50
3	5.0038	5.65	0.89	2.9056	0.55
4	5.0038	5.81	0.86	2.8256	0.65
5	5.0038	5.47	0.91	3.0012	0.65
6	5.0038	5.27	0.95	3.1151	0.75
7	5.0038	3.96	1.26	4.1456	1.50
8	5.0038	4.13	1.21	3.9750	1.45
9	5.0038	4.31	1.16	3.8090	1.25
10	5.0038	4.13	1.21	3.9750	1.30

$C_{T,M}$	$R_{n,M}$	$C_{F,M}$	$C_{R,S}$
0.06492774	353866.0427	0.005955095	0.05897265
0.04296747	355171.8215	0.00594973	0.03701774
0.05136069	340713.4996	0.006010687	0.04535000
0.06418549	331330.6837	0.006052174	0.05813332
0.05689305	351925.2783	0.005963119	0.05092994
0.06093316	365281.0764	0.005909089	0.05502408
0.06881021	486119.0082	0.005517923	0.06329228
0.07235013	466109.2669	0.005572975	0.06677716
0.06792596	446642.9867	0.005629696	0.06229627
0.06486564	466109.2669	0.005572975	0.05929266

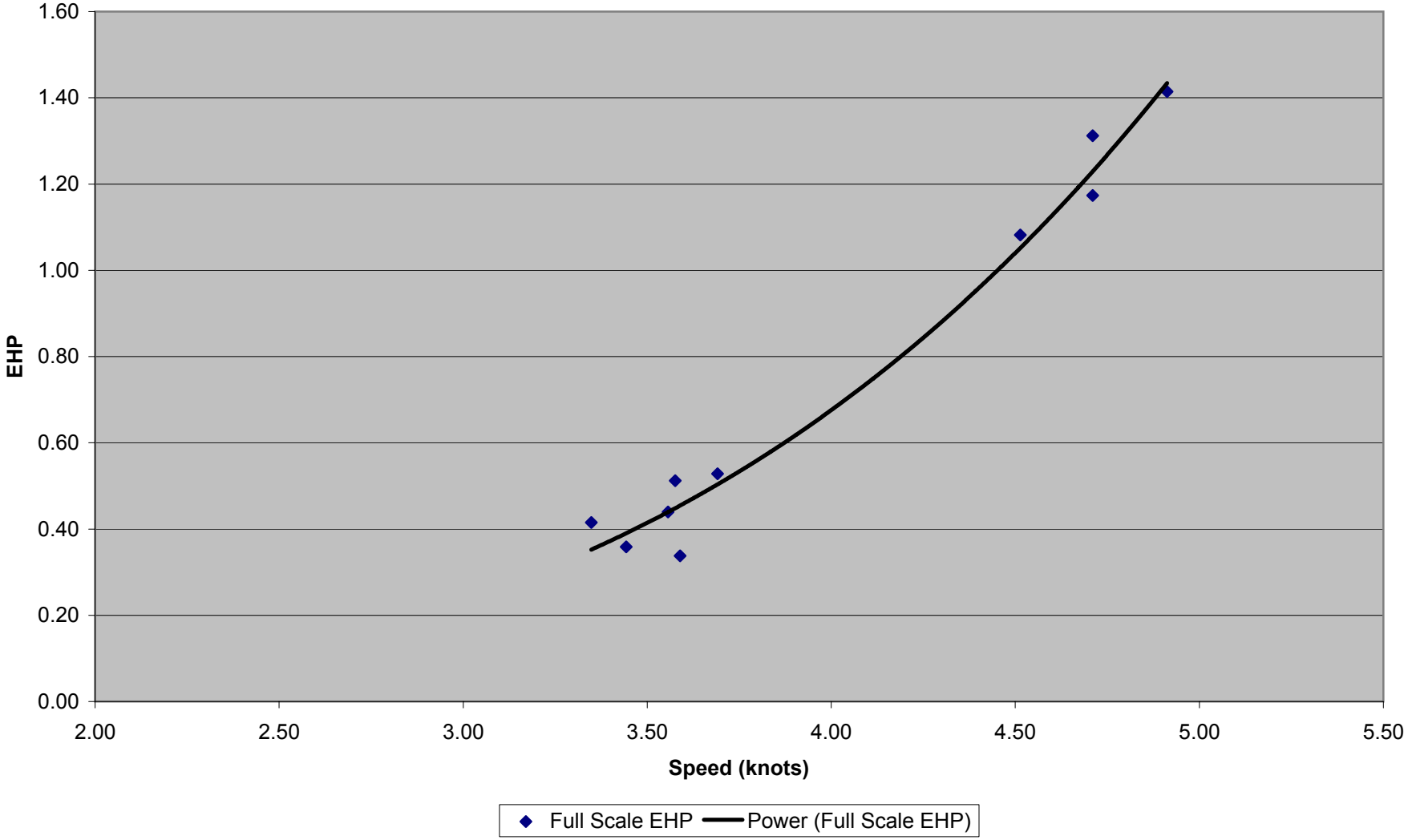
V_S (ft/s)	$R_{n,M}$	$C_{F,S}$	$C_{T,S}$	V_S (knots)
6.04	2830928.342	0.003784119	0.06315677	3.58
6.06	2841374.572	0.003781402	0.04119914	3.59
5.81	2725707.996	0.003812239	0.04956224	3.44
5.65	2650645.47	0.003833172	0.06236649	3.35
6.00	2815402.227	0.003788183	0.05511812	3.56
6.23	2922248.611	0.003760788	0.05918486	3.69
8.29	3888952.066	0.003560144	0.06725243	4.91
7.95	3728874.136	0.003588633	0.07076579	4.71
7.62	3573143.893	0.003617898	0.06631416	4.51
7.95	3728874.136	0.003588633	0.06328130	4.71

$R_{T,S}$ (lb)	EHP
46.69	0.51
30.68	0.34
33.97	0.36
40.42	0.42
40.30	0.44
46.62	0.53
93.83	1.41
90.77	1.31
78.10	1.08

Plot of Full Scale Total Resistance of Nominal Size Displacement Hull: L = 5 ft, B = 3.5 ft, Displacement = 288 lbs versus Full Scale Hull Speed In Knots



Plot of Full Scale EHP versus Full Scale Vessel Speed for Nominal Size Displacement Hull: L = 5 ft, B = 3.5 ft, Displacement = 288 lbs



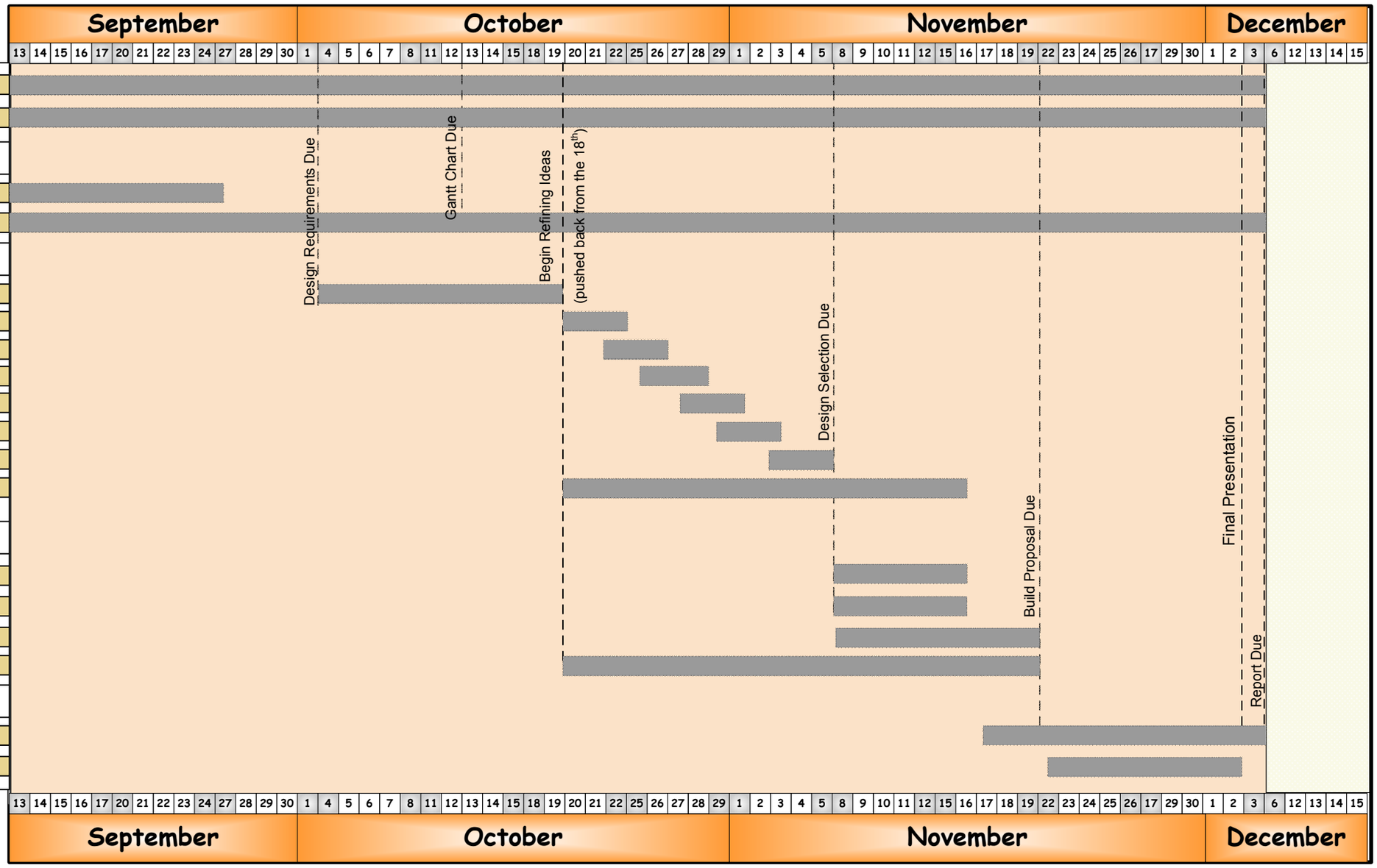
APPENDIX E – GANTT CHARTS

TRITON ROBOTICS

Aaron Caldwell	= A
Amy MacFarlane	= AM
Guillaume Gervais	= G
Jeramy Slaunwhite	= J
Michael Carter	= M
Robert Vaughan	= R
Entire Group	= E

COMPLETE | NOT COMPLETE

13-October-04

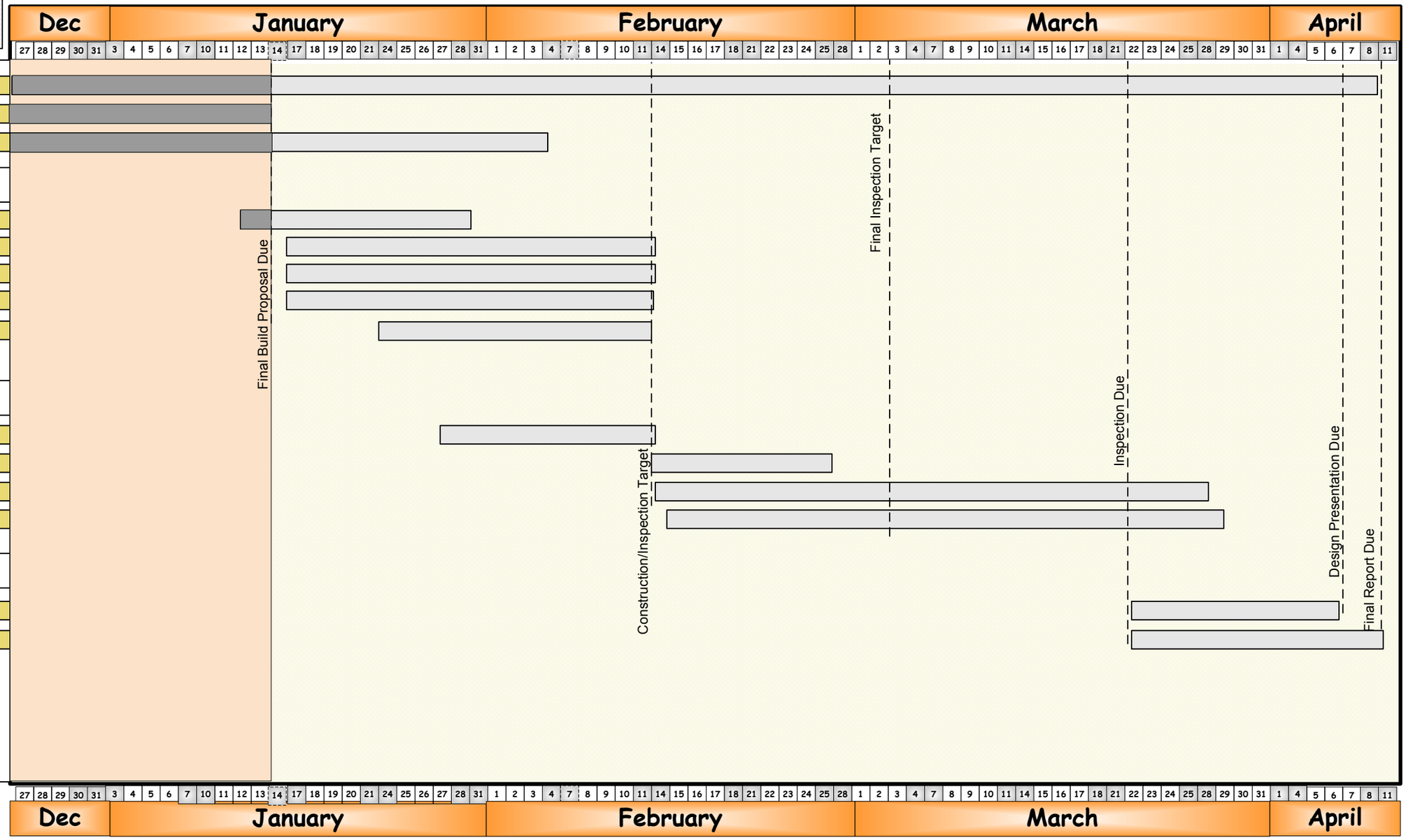

September
October
November
December
13 14 15 16 17 20 21 22 23 24 27 28 29 30 1 4 5 6 7 8 11 12 13 14 15 18 19 20 21 22 25 26 27 28 29 1 2 3 4 5 8 9 10 11 12 15 16 17 18 19 22 23 24 25 26 17 29 30 1 2 3 6 12 13 14 15
Website (J)
Research (E)
Design Requirements
Mission Statement (M, R, AM, G)
Consultation w/Client (AM)
Design
Brainstorming (E)
Hull Design (R)
Electronics Integration (A)
Propulsion Design (M)
Control Design (AM)
Waterproofing (G)
Cooling Considerations (J)
Testing/ Modeling (E)
Build Proposal
Budget (AM)
Material Selection (G)
Assembly (A, J, R)
CAD Drawings (A, J, R)
Final Deliverables
Report Writing (AM, G, M)
Presentation Preparation (AM, G, M)
Design Requirements Due
Gantt Chart Due
Begin Refining Ideas
(pushed back from the 18th)
Design Selection Due
Build Proposal Due
Final Presentation
Report Due

Aaron Caldwell	= A
Amy MacFarlane	= AM
Guillaume Gervais	= G
Jeramy Slaunwhite	= J
Michael Carter	= M
Robert Vaughan	= R
Entire Group	= E

TRITON ROBOTICS

COMPLETE | NOT COMPLETE

14-January-05


Dec
January
February
March
April
27 28 29 30 31 3 4 5 6 7 10 11 12 13 14 17 18 19 20 21 24 25 26 27 28 31 1 2 3 4 7 8 9 10 11 14 15 16 17 18 21 22 23 24 25 28 1 2 3 4 7 8 9 10 11 14 15 16 17 18 21 22 23 24 25 28 29 30 31 1 4 5 6 7 8 11
Website (J, G)
Final Build Proposal (A, J, R)
Material Acquisition (AM, G, M)
Construction
Hull (E)
Electrical (A, AM, G)
Propulsion (A, J, M)
Control System (AM, J, M)
Array (G, J, R)
Testing/ Modeling
Hull (A, AM)
Propulsion (M, J)
Entire Vessel (R, G)
Modifications/ Fixes (E)
Deliverables
Presentation (A, J, R)
Final Report (AM, G, M)
Final Build Proposal Due
Construction/Inspection Target
Final Inspection Target
Inspection Due
Design Presentation Due
Final Report Due